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ABSTRACT

This document contains investigations for topics 1-4 in the earth science course developed by the University of the State of New York for secondary schools. Topics include observation and measurement, the changing environment, measuring the earth, and earth motions. Each topic is preceded by the Investigations-Understandings Matrix which illustrates the relationship of the investigation to the major understandings. It can also be used to relate multimedia materials to the topic. The laboratory investigations are presented in two forms: teacher laboratory guide sheets and student laboratory guide sheets, which may be duplicated to provide structured procedure for the students. The level of difficulty of each investigation is indicated on the teacher guide sheet as easy, challenging, or difficult. Although these activities are in a supplement, they are considered essential to the core of the course. (SL)

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EARTH SCIENCE

SUPPLEMENT TO THE SYLLABUS

ED 141137

PART 1, TOPICS 1-4

U.S. DEPARTMENT OF HEALTH, EDUCATION & WELFARE
NATIONAL INSTITUTE OF EDUCATION

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SPECIAL EDITION

1970

The University of the State of New York
THE STATE EDUCATION DEPARTMENT
Bureau of Secondary Curriculum Development
Albany, New York 12224

SE 022 648

TO THE TEACHER

Earth science teachers realize that the investigatory approach is the key to good science teaching. The investigations included in the Supplement are suggestive and not mandatory. Many earth science teachers have an extremely sophisticated repertoire of laboratory experiences which will complement the syllabus approach. Teachers who are willing to share their laboratory approaches with others are urged to send copies to the Bureau of Science Education for possible inclusion in new printings of the Supplement.

The Investigations-Understandings Matrix correlates the understandings and investigations, and indicates the understandings which are included in any single investigation. This matrix will show areas in need of supplementary expansion.

Teachers may wish to add their own investigations, field trips, and multimedia to the matrices.

MULTIMEDIA BY TOPICS

KEY - (F) Film (P) Periodical (B) Book (FS) Filmstrip (FL) Film Loop

TOPIC I - OBSERVATION AND MEASUREMENT

(F) Evidence for Molecules and Atoms - 19 min. sound - color; Encyclopedia Britannica Films

(F) The Story of Palomar - 40 min. sound - b/w or color; Encyclopedia Britannica Films

(F) Come and Find Me - 24 min. sound - color; Pure Oil Company

(F) Science of the Sea - 19 min. sound - color; International Film Bureau

(F) The Hidden Earth - 29 min. sound - b/w or color

(F) Be Your Own Weatherman - 12 min. sound - b/w or color; Cenco Educational Films

(F) The Strange Case of the Cosmic Rays - 53 min. sound - color; Bell Telephone System

(P) Scientific American "Ice" 12/66, "Water" 4/56 (R)
"Remote Sensing of Natural Resources" 6/68

(P) American Scientist "Aerial Photography - A Valuable Sensor for the Scientist" 3/64; "Earth Science and the Electron Microscope" Summer/68

(P) Chemistry "The Significant Structure of Water" 9/66

TOPIC II - THE CHANGING ENVIRONMENT

(F) Erosion - 6 min. sound - b/w; U. S. Soil Conservation Service

(F) Friendly Waters - 7 min. sound - color; Soil Conservation Service

(F) From the Group Up - 13 min. sound - color or b/w; Soil Conservation Service

(F) Watershed Wildfire - 21 min. sound - color or b/w; U. S. Forest Service

(F) The River Must Live - 20 min. sound - color; Shell Oil Company

TOPIC III - MEASURING THE EARTH

(F) By Map and Compass - 26 min. sound - color; International Film Bureau

(F) The Impossible Map - 11 min. sound - b/w or color; National Film Board of Canada

(F) How We Know the Earth's Shape - 10 min. sound - b/w or color; Film Associates of California

(F) Global Concept in Maps - 11 min. sound - b/w or color; Coronet Films

(F) What's Under the Ocean - 13 min. sound - b/w or color; Film Associate of California

(FS) Maps and Earth Measurements. AGI-EBF

(P) Scientific American
"The Shape of the Earth" 10/67 (R);
"The Earth's Gravity" 9/55 (R);
"Gravity" 3/61 (R);
"Atmospheric Tides" 12/62;
"Magnetic Fields on the Quiet Sun" 11/66;
"The Magnetic Properties of Materials" 9/67;
"The Earth as a Dynamo" 5/58 (R)

(P) Natural History "Astronomer's Odd Figure" 10/62

TOPIC IV - EARTH MOTIONS

(F) Ocean Tides - Bay of Fundy - 15 min. sound - color; Encyclopedia Britannica Films

(F) How We Know the Earth Moves - 10 min. sound - b/w or color; Film Associates of California

(F) Frames of Reference - 26 min. sound - b/w; Modern Learning Aids

(F) Elliptic Orbits - 20 min. sound - b/w; Modern Learning Aids

(P) "The Voyage of Mariner IV" 3/66; Scientific American "The Origins of the Copernican Revolution"10/66;

(P) American Scientist "A strategy for Mars" 12/65

TOPIC V - ENERGY IN EARTH PROCESSES

(F) Matter and Energy - 11 min. sound - b/w or color; Coronet Films

(F) The Mystery of the Sun - 25 min. sound - b/w; Carousel Films

(F) Our Mr. Sun - 68 min. sound - color; Bell Telephone System

(F) Our Nearest Star - 29 min. sound - b/w or color; McGraw-Hill Text Films

(P) "The Energy Environment in Which We Live" 9/67 American Scientist "Direct Use of the Sun's Energy" 3/67

(P) Scientific American "The Solar Wind" 4/64

(P) Natural History "A Storm's Incalculable Energy" 4/65

TOPIC VI - INSOLATION AND THE EARTH'S SURFACE

(F) Our Mr. Sun - 68 min sound - color; Bell Telephone System

(F) The Unchained Goddess - 55 min. Bell Telephone

(F) What Makes the Wind Blow? Encyclopedia Britannica Films - AGI

TOPIC VII - ENERGY EXCHANGES IN THE ATMOSPHERE

(F) The Earth: Its Atmosphere - 11 min. Encyclopedia Britannica Films - AGI

(F) The Inconstant Air - 27 min. McGraw-Hill, 1960

(F) The Unchained Goddess - 55 min. Bell Telephone

(F) Origin of Weather - 26 min. Carousel, 1958

(F) Sky - 10 min. sound - b/w; National Film Board of Canada

(F) Snow - 13 min. sound - b/w; National Film Board of Canada

(F) Be Your Own Weatherman - 12 min. Cenco, 1962

(F) What Makes the Wind Blow? Encyclopedia Britannica Films - AGI

(FS) The Mystery of Rain Maelstroms of the Air, "Life" Magazine

(FS) The Canopy of Air, "Life"

(P) Natural History

"A Storm's Incalculable Energy" 4/66
"For Cloud Watchers" 6, 7/68
"Lightning Through a Lens" 1/66
"Inside the Tornado" 4/68

(P) Scientific American

"Micrometerology" 10/64
"Noctilucent Clouds," 6/63
"Ice Waves in the Atmosphere" 3/61
"The Circulation of the Upper Atmosphere" 9/62
"The Antarctic and the Upper Atmosphere" 9/62 (R)
"Ball Lightning" 3/63
"The Origin of the Atmosphere" 8/53
"Artificial Satellites and the Earth's Atmosphere" 8/59 (R)
"The Circulation of the Atmosphere" 12/56 (R)
"The Origin of Hurricanes" 8/57 (R)
"Tornadoes" 5/58 (R)
"Salt and Rain" 10/57 (R)
"Sun Clouds & Rain Clouds" 4/57 (R)
"Fog" 12/68
"Weather Satellites" 1/69

(P) American Scientist

"The Energy Environment in Which We Live" 9/63
"The Circulation of the Atmosphere" 12/66
"Telltale Dust" 3/64

(B) *The Earth Sciences*, Strahler Chapters 13, 14, 15

(B) *Geology and Earth Sciences Sourcebook* Chapter 7

TOPIC VIII - MOISTURE AND ENERGY BUDGETS AND ENVIRONMENT CHANGE

(F) The River Must Live - 20 min. sound - color; Shell Oil Co.

(F) California and Its Natural Resources - 40 min. sound - color; U. S. Bureau of Mines

(F) The Desert - 11 min. sound - color; Arthur Barr Productions

(F) The Face of the High Arctic - 13 min. sound - b/w or color; National Film Board of Canada

(F) The Making of the River - 10 min. sound - b/w or color; Coronet Films

(F) Rivers in Miniature - 14 min. sound - color; U. S. Army Corps of Engineers

(F) Water: Fountain of Life - 15 min. sound - color; Standard Oil Co. of California

(FS) Pollution - Wards 71W25004

TOPIC IX - THE EROSIONAL PROCESS

(F) Erosion - 6 min. sound - b/w; U. S. Soil Conservation Service

(F) The Making of the River - 10 min. sound - b/w or color; Coronet Films

(F) Our Soil Resources - 11 min. sound - b/w; Encyclopedia Britannica Films

(F) Rivers in Miniature - 14 min. sound - color; U. S. Army Corps of Engineers

(F) Shackles for the Giant - 25 min. sound - color; U. S. Army Corps of Engineers

(F) What Is Soil? - 10 min. Sound - b/w; Encyclopedia Britannica Films, (University of Washington Film Library)

(F) White Thunder - 13 min. sound - color; Ford Motor Company

(P) Scientific American

"Soil" 7/50 (R)
"Sand" 4/60 (R)

TOPIC X - THE DEPOSITIONAL PROCESS

(F) Marshes of the Mississippi - 12 min. sound - color; Avalon Daggett

(P)

Scientific American

"Sand" 4/60 (R);
"The Origin of Submarine Canyons" 5/60, 8/56 (R);
"The Seas' Deep Scattering Layers" 3/63 (R)

TOPIC XI - FORMATION OF ROCKS

(F) Rocks That Form at the Earth's Surface - 16 min. sound - color; AGI-EBF

(F) Rocks That Originate Underground - 23 min. sound - color; AGI-EBF

(F) Why Do We Still Have Mountains? - 20 min. sound - color; AGI-EBF

(F) Rocks and Minerals - 11 min. sound - color; Film Associates of California

(F) How Solid Is Rock? - 20 min. sound - color; EBF-AGI

(P)

Scientific American

"The Origin of Granite" 4/55 (R)
"The Growth of Crystals" 3/55 (R)

TOPIC XII - THE DYNAMIC CRUST

(F) Why Do We Still Have Mountains? - 20 min. sound - color; AGI-EBF

(F) The Hidden Earth - 20 min. sound - color; McGraw-Hill

(F) The Interior of the Earth - 14 min. sound - color; McGraw-Hill

(P)

Scientific American

"Anatomy of the Atlantic" 1/55;
"Geological Subsidence" 6/67;
"The Plastic Layer of the Earth's Mantle" 7/62;
"The Mohole" 4/59;
"Reversals in the Earth's Magnetic Field" 2/67;
"Confirmation of Continental Drift" 4/68;
"Sea-Floor Spreading" 12/68;
"The Interior of the Earth" 9/55;
"Insects in Amber" 11/51 (R);
"Crises in the History of Life" 2/63;
"Elephant Hunting in North America" 6/55;
"Charles Darwin" 2/56 (R);
"Darwin's Finches" 4/53 (R);
"The Coelacanth" 12/55 (R);
"Early Man in Africa" 7/58 (R);
"Radiocarbon Dating" 2/52 (R);
"Darwin's Missing Evidence" 3/59 (R);
"Precambrian Animals" 3/61;
"Micropaleontology" 7/62 (R);
"The Origin of the Earth" 10/52 (R);
"Corals as Paleontological Clocks" 10/66 (R);
"Chemical Fossils" 1/67;
"Fossil Behavior" 8/67 (R);
"The Earliest Apes" 12/67;
"Neanderthal" 12/57 (R);
"A Stone-Age Campsite at the Gateway to America" 6/68;
"Homo Erectus" 11/66;
"The Evolution of Intelligence" 1/65;
"Early Relatives of Man" 7/64;
"The Origin of Life" 8/54 (R);
"Ancient Temperature" 2/58 (R);
"The Ape Men" 11/49 (R);
"Charles Lyell" 8/59 (R);
"The Petrified Forest of Yellowstone Park" 4/64;
"The Ancient Life of the Antarctic" 9/53

(P)

American Journal of Science

"Origin of Continental Slopes" 3/64;
"Continental Drift and a Dynamic Earth" Spring,68

(P)

National Geographic

"On a Peaceful Good Friday, Alaskans Felt the Dread Earthquake" 7/64;
"The Night the Mountains Moved" 3/60;
"Fountain of Fire in Hawaii" 3/60

(P) American Scientist

"The Strategy of Evolution" 9/64;
"Metasequoia - A Living Fossil" 3/64;
"Riddles of the Terrible Lizards" 6/64;
"Origin of the Cambrian-PreCambrian Unconformity" 12/66;
"The Origin and Evolution of Human Culture" 3/63;
"Humanoids on Other Planets" 12/64;
"The Evolution of Human Intelligence" 9/65;
"The Human Revolution" 3/64

TOPIC XIII - INTERPRETING GEOLOGIC HISTORY

(F) Random Events - 31 min. sound - b/w; Modern Learning Aids

(F) Long Time Intervals - 25 min. sound - b/w; Modern Learning Aids

(F) Nuclear Radiation in Earth Studies - 15 min. sound - b/w; Cenco Educational Films

(F) From Water to Land - 28 min. sound - color; McGraw-Hill Text Films

(F) The Petrified River - 28 min. The Story of Uranium - U. S. Bureau of Mines

(F) In the Beginning - 28 min. John J. Hennessy

(F) Grand Canyon - 30 min.

(FS) AGI-EBF Filmstrip - record set on fossils
1. How Fossils Are Formed
2. How To Collect Fossils
3. Fossils and the Relative Age of Rocks
4. Fossils and Prehistoric Environment
5. Fossils as Evidence of Organic Change

(FL) Grand Canyon - Geologic Formations

(FL) Grand Canyon - River

(P) American Scientist "Origin of the Cambrian - Precambrian Unconformity" 12/66

(P) Natural History

"The Grand Canyon, The Canyon and The River" 11/67;
"Geology's Time Clock" 5/62;
"Unraveling the Age of Earth and Man" 2/67;
"Armor Plated and Jawless Devonian Fish" 8/64;
"A Natural History of Trilobites" 8/61;
"Emerging Man in Africa" 11/62

(B) Geology of New York, Educational Leaflet #2, N.Y.S. Museum and Science Service

(B) SRA Inquiry Development Program in Earth Science:

Problem Book
Resource Book
Teacher's Guide
Idea Book
By J. R. Suchman & L. McCombs

TOPIC XIV - LANDSCAPE DEVELOPMENT AND ENVIRONMENTAL CHANGE

(F) Continental Glaciers - 13 min. sound - color; Ohio State University

(F) The Face of the High Arctic - 13 min. sound - bw or color; National Film Board of Canada

(F) Glacier National Park - 22 min. sound - color; Modern Talking Pictures

(F) Glacier Park Studies - 22 min. sound - color; Bailey Films

(F) Men Against the Ice - 24 min. sound - b/w; National Film Board of Canada

(F) Monument Valley - 17 min. sound - color; Paul Hoefler Productions

(F) The Mountain Movers - 11 min. sound - b/w; National Film Board of Canada

(F) Navajo Canyon Country - 11 min. sound - b/w; National Film Board of Canada

(F) Physical Regions of Canada - 23 min. sound - b/w; National Film Board of Canada

(F) Snow - 13 min. sound - b/w; National Film Board of Canada

(F) Washington and its Natural Resources - 26 min. sound - color; U. S. Bureau of Mines

(F) Wilderness Alps of Stehekin - 28 min. sound - color; Sierra Club

(F) Yosemite - 22 min. sound - b/w or color; Encyclopedia Britannica Films

topic I

TOPIC I - OBSERVATION AND MEASUREMENT

How Can the Environment Be Investigated?

Time Emphasis: 5 days

TOPIC OUTLINE

INVESTIGATION		A-1a	A-1b	A-2a	B-1a	B-1b
Estimated Time (Periods)		1½	1	1	3	2
A. The local environment						
A-1 Observation						
A-1.1 Sensory perception	A-1.11					
A-1.2 Sensory limitations	A-1.21					
	A-1.22					
A-1.3 Inferences	A-1.31					
A-2 Classification						
A-2.1 A system of classification	A-2.11					
A-2.2 Purpose	A-2.21					
B. Properties of the environment						
B-1 Measurement						
B-1.1 Dimensional Quantities	B-1.11					
	B-1.12					
B-1.2 Comparison	B-1.21					
B-1.3 Error	B-1.31					
B-2 Density						
B-2.1 Variations	B-2.11					
	B-2.12					
	B-2.13					
	B-2.14					

How Can the Local Environment Be Observed?

How Can Observations of the Environment Be Classified?

How Can Properties of the Environment Be Measured?

What Are Some Characteristics of the Properties of the Environment?

PROCESS OF INQUIRY OBJECTIVES

Mathematical Skill	PIO-1
Measurement Skill	PIO-2
Creating Models	PIO-3
Analysis of Error	PIO-4
Data Analysis	PIO-5

TITLES

Multimedia: Check Multimedia Section of Supplement for reference to this topic.

- Shoebox Observations
- Puddle Observations
- Classification
- Density
- Variable Density of Water

Easy (1.5)

I-A-1a: SHOEBOX OBSERVATIONS

QUESTION:

How can the local environment be observed?

MATERIALS:

One set of observation boxes made of cardboard or wood for every 10 students:

Box 1. top replaced with transparent food wrap; four or five objects, such as rocks, clay, coins, or a vial of liquid, cemented to the bottom. Objects should have some characteristics which are not observable by the sense of sight; attach a label which conforms with the student laboratory guide.

Box 2. one end of the box replaced with a cloth curtain, three doubled sandwich bags, each filled with different sized particles (e.g., cornmeal, sand, shot, flour). Attach the proper label.

Box 3. lid tightly taped shut; one or two familiar objects loose in box (e.g., tacks, paper clips, rubber stoppers). Attach the label.

Box 4. top with holes punched at regular intervals or replaced with pegboard; make available a dowel or knitting needle for poking through holes. A plastic mountain model or irregularly-shaped plaster model is placed in the box; label.

Box 5. top removed; place into the box plaster of paris in a paste form which will harden within the observation time or use a small lump of silly putty; label.

SUGGESTED APPROACH:

1. Explain procedures for the investigation; emphasize the observing of properties or characteristics rather than naming objects.

2. Set boxes at numbered stations; have students move from station to station, spending about 3 minutes at each one making observations.

3. After all observations have been made, compare students' observations; encourage students to challenge and comment on each others' observations; bring out the distinction between observations and interpretations, the range of properties observed by different students at the same station, the difference between identifying or naming an object and determining its properties, the comparison between the limitations imposed by the instructions at each station and those faced by earth scientists observing the earth.

REFERENCES:

Investigating the Earth, p. 4, Teachers Guide, pp. 20-22
Our Planet in Space, Chapter

I-A-1a: SHOEBOX OBSERVATIONS

QUESTION:

How can the local environment be observed?

INTRODUCTION:

As you examine several objects, you will make observations of their characteristics. Observation making is an activity that is basic to science.

OBJECTIVES:

When you finish this investigation, you should be able to:

1. make and record observations.
2. explain why it is often desirable to use instruments in making observations.
3. make inferences based on observations.
4. distinguish between observations and inferences.

METHOD:

- Follow the directions on each box at each station
- Spend about 3 minutes at each of the five stations.

Station No. 1: DO NOT TOUCH THIS BOX. Look at the objects inside the box. Observe and describe as many properties of these objects as you can.

Station No. 2: DO NOT LIFT THIS BOX, REMOVE THE LID, OR LOOK INSIDE. Reach inside the box through the curtained opening at the end. From the feel of the materials, describe the properties of the objects in the box.

Station No. 3: DO NOT REMOVE THE LID FROM THIS BOX. You may lift, gently shake, or tip this box to observe the properties of the object, or objects, inside the box.

Station No. 4: DO NOT LIFT THIS BOX OR REMOVE THE LID. Poke the stick straight down through any 10 holes to determine the properties of the object or objects in the box.

Station No. 5: YOU MAY touch, smell, lift, or examine the material in this box in any way that will help you determine its properties.

QUESTIONS:

(A-1.11) 1. How did you make observations at each of the five stations?

(A-1.21) (A-1.22) 2. How were you able to extend your powers of observation at station No. 4? Why was it necessary?

(A-1.31) 3. What inferences can you make about the objects in each box based on your observations?

Challenging (1)

I-A-1b: PUDDLE OBSERVATIONS

QUESTION:

How can the local environment be observed?

MATERIALS:

One or more mud puddles, preferably partially dried up.
Optional - metric rulers, camera, cork borers for taking core samples, knives.

SUGGESTED APPROACH:

1. Take the class to a nearby puddle; raise one question: What has happened here?
2. Have students make careful observations of the puddle.
3. Have students discuss their observations and draw inferences.

MODIFICATIONS:

1. Have a student or a committee of students take a series of photographs of the puddle from the same location, in order to show changes in it over a period of time. Make a time-lapse movie if possible.
2. Relate the features and processes observed at the puddle with features and processes observed at a lake or pond. Note the similarities and differences between a pond and a puddle.
3. Have students begin a long-term investigation of a pond or lake to which they have access.
4. Prepare a series of "artificial puddles" in shallow trays or pans. Use a variety of colored silts to show depositional layering and runoff patterns--heat lamps may be used to hasten evaporation.

I-A-1b: PUDDLE OBSERVATIONS

QUESTION:

How can the local environment be observed?

INTRODUCTION:

To help you develop your powers of observation, carefully and thoughtfully examine a mud puddle. Use whatever means you can. You will then be able to use the observations to predict future events at the puddle site.

OBJECTIVES:

When you finish this investigation, you should be able to:

1. make and record observations.
2. describe the purpose for the use of instruments in making observations.
3. make inferences based on observations.
4. distinguish between observations and inferences.

METHOD:

1. Carefully examine the puddle in any way you can. Record your observations.
2. Use your observations to explain, to the best of your ability, what has happened to the puddle site to make it appear as it does now.
3. Use your observations and interpretations to make predictions about the future of the puddle site.

QUESTIONS:

(A-1.11) 1. How did you make observations of the puddle?

2. What caused the puddle?
3. What determined the depth of the puddle?
4. What is the evidence that loose material in the puddle area has been moved?

(A-1.11) 5. How many events of rainfall can you determine have occurred? What is the evidence of wind?

6. What is the evidence of animal life?

7. What are some events that are likely to happen to this puddle in the future?

(A-1.31) 8. a) Which of your previous answers were observations?
b) Which were inferences?
c) Which were predictions?

(A-1.21) (A-1.22) 9. What is the purpose of the use of instruments in a detailed investigation?

Easy (1)

I-A-2a: CLASSIFICATION

QUESTION:

How can the observations of the local environment be classified?

MATERIALS:

A wide variety of items representative of the students' local environment (e.g., pebbles, water, oil, air, slice of bread, Band-Aids, sand, potato, bottle of catsup, cucumbers, rubber stoppers, strips of metal, pieces of wood, boxes of detergent and cereal, apples, can of frozen juice, etc.).

SUGGESTED APPROACH:

1. Provide the students with samples of their environment and the student investigation sheet. The students should be asked to classify these samples in some way that is meaningful to them and to explain the basis for their classification system.
2. After all groups have completed their classifications, encourage them to challenge and defend each other's ideas.
3. Introduce a discussion based on "Why does man classify items in his environment?" Interject into the discussion the idea that classification probably exists because of man's inability to comprehend a large number of individual items; therefore, he is forced to categorize them.

PRECAUTIONS:

The teacher must be careful not to channel the student's thinking into a preconceived classification system. Encourage the students to arrive at their own system with as little guidance as possible.

MODIFICATIONS:

1. Make a pile of shoes by obtaining one from each student. Select one student to separate the pile by some classification system. Other students should identify the system being used. A second student may be called upon to repeat the procedure using a different system.
2. Students may be asked to bring small objects to school. The random assortment of items should prove interesting to classify.
3. If the classification of natural earth materials is desired, an assortment of pebbles obtained from beaches, gravel pits, along roadsides, and in stream beds may be used.

REFERENCES:

Investigating the Earth, pp. 36-38, Teachers Guide, pp. 69-70.
Our Planet in Space, pp. 64-68.

I-A-2a: CLASSIFICATION

QUESTION:

How can the observations of the local environment be classified?

INTRODUCTION:

Consciously or unconsciously we tend to classify all things into groups because it makes identification more convenient. Much of science is based on classification systems.

OBJECTIVES:

When you finish this investigation you should be able to:

1. given a group of objects, develop a classification system that can be used to classify a given group of objects.
2. describe the basis of your classification system and defend the placement of each object that has been categorized.

METHOD:

1. Carefully observe the properties of the samples provided.
2. Group the samples of similar properties and describe the basis for your classification system.
3. Using the same samples, derive a second system.

QUESTIONS:

(A-1.11) 1. How did you become aware of the properties of these items?

2. How many groups were necessary to classify your samples?
3. What properties did the objects in each group have in common?

(A-2.11) 4. What was the basis for your classification system?

Challenging (3)

I-B-1a: DENSITY

QUESTION:

How can properties of the environment be measured?

MATERIALS:

Plastic column kits, graduated cylinders, water, alcohol, ice cubes, rock samples (e.g., granite and basalt), graph paper.

SUGGESTED APPROACH:

1. Have available a container of water labeled "Fluid A" and a similar container of alcohol labeled "Fluid B." Ask students how the volumes of these fluids could be determined. A variety of approaches to the problem may result and can be pursued as long as the method involves comparison to a standard. One approach might be to use a plastic column which the student can calibrate with a grease pencil. The basis can be either displacement of a fluid by a solid object of known volume or direct measurement of the tube dimensions and computation of volume.

2. Provide a number of variously shaped glass containers filled to different levels with "Fluid A" and "Fluid B." Ask students what kind of relationship, if any, exists between volumes and masses of the samples. Indicate that one way of determining this is to measure the relationship of a number of samples and prepare a graph of the results. Have half the class work with "Fluid A" and the other half with "Fluid B." At this time more accuracy can be achieved by using graduated cylinders instead of student-calibrated tubes.

3. Have students plot a curve for both "Fluid A" and "Fluid B" on the same graph.

4. Have students describe each curve and predict where points would occur for samples that are larger and smaller than those measured.

   They should also arrive at the conclusion that one line is steeper than the other. With the teacher's assistance, the students should develop the ability to describe the slopes numerically in terms of change in mass over change in volume, or rise to run (i.e., the alcohol curve should rise approximately 0.8 squares on a run of one square, producing a slope of $\frac{0.8}{1}$ or 0.8.

5. Inform students that the numerical value $\frac{\text{mass}}{\text{volume}}$ which is unique to the substance is called density.

6. Demonstrate that an ice cube dropped into "Fluid A" will float while an ice cube in "Fluid B" will sink. Ask the students to predict and sketch a line on their "Fluid A and B" graphs representing the density of ice.

   The students should be asked to measure the density of an ice cube. Allow them to pursue any reasonable technique. At the end of the exercise, point out that no measurements other than observing the demonstration would have been necessary to determine the approximate density. In effect, fluids "A" and "B" could have been used as standard densities and the ice compared to each (i.e., ice floated in "A" and is therefore less dense, ice sank in "B" and is therefore more dense).

7. Provide samples of common, solid earth materials (e.g., granite and basalt) and have students find the densities of the materials.

8. Have students determine standard densities of materials used (either by averaging their results or by referring to density tables) and compute the percentage of error. Have students compile a list of possible sources of error and discuss ways that the results could be improved.

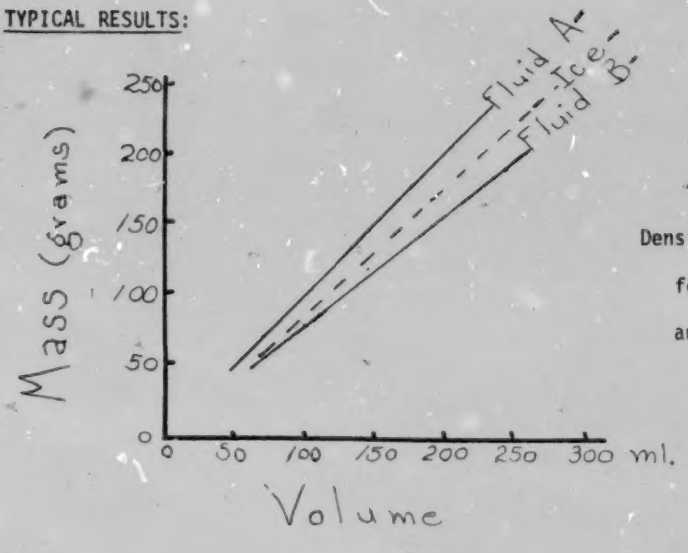
PRECAUTIONS:

1. This lab is not designed to be completed during one average class period. Convenient breaking points occur following Suggested Approaches 1, 5, and possibly 6.

2. If students are well versed in measurement from previous training, Suggested Approach #1 may be eliminated.

3. Duplicating fluid may be used in place of alcohol, but check its density.

TYPICAL RESULTS:



Density Graph - for Fluid A, Fluid B, and Ice

MODIFICATIONS:

1. Introduce the topic of density by using two identical appearing bottles as a demonstration. One should be filled with a low density material (i.e., air), the other with a high density material (i.e., sand). Give a bottle to each of two students on opposite sides of the room. Ask the students to describe the bottles to each other and the class. Have the students exchange bottles and make comparisons. Discuss how and why the bottles were different; point out the difference in density.

2. Have the students determine the densities of various given objects. Suggest that they record data in a table listing the name of the object, its mass, volume, and density.

3. After the students have determined the densities of the objects, record the densities on the blackboard. If values do not agree, have the students suggest reasons for differences.

4. Using the recorded densities, have students discuss the effect a difference in shape or size has on the density of the same material, and the effect a difference in material has on the density of materials of the same size and shape.

REFERENCES:

Investigating the Earth, pp. 6-7, Teacher's Guide, pp. 23-27

I-B-1a: DENSITY

QUESTION:

How can properties of the environment be measured?

INTRODUCTION:

You often hear statements like "lead is heavier than water" or "gold is the heaviest material on earth." These statements are not necessarily true, for if you had a barrel of water it would certainly be heavier than a lead shot. What is implied, of course, is that if the volumes of the two substances are identical, then the lead would be heavier. This property of matter is called density.

OBJECTIVES:

When you finish this investigation, you should be able to:

1. determine the volume of a sample of a substance with reasonable accuracy.
2. measure the mass of a sample of a substance with reasonable accuracy.
3. determine the density of a substance from mass and volume data.
4. describe the relationship between the mass and volume of different samples of the same substance.
5. calculate the percentage error between calculated and standard values.
6. list some reasons for deviations between calculated and standard values in terms of experimental procedure.

METHOD:

1. Devise a method for measuring the volumes of fluids "A" and "B."
2. Investigate the relationship between volume and mass of the samples of liquids. Graphing may aid you in recognizing the relationship.
3. Based on your graph interpretation of fluids "A" and "B," make predictions concerning the masses of larger and smaller volumes than those used to construct the graph.
4. Describe the differences between the lines of the graph. How could you describe these differences numerically?

5. Find the approximate density of an ice cube, and sketch a line on your graph for the density of ice.

6. Find the densities of the samples of solid earth materials provided by your teacher. Compute the percentage of error, and discuss possible sources of the error.

QUESTIONS:

(B-1.11) 1. What are the least number of basic dimensional quantities you have used to describe all of the measurements you have made? List them.

(B-1.12) 2. Which of the properties of matter investigated were based on a mathematical combination of two or more basic quantities?

(B-1.21) 3. Which of the measurements made were direct comparisons with known standards?

(B-1.31) 4. Were any of the measurements accurate determinations of the absolute value of that quantity? Explain.

(B-2.11) 5. What effect does size or shape have on the density of objects made of the same material?

Challenging (2)

I-B-1b: VARIABLE DENSITY OF WATER

QUESTION:

How can properties of the environment be measured?

MATERIALS:

Plastic shoe boxes (or some other relatively large, transparent container), small ice cubes (preferably dyed with food coloring), at least three Celsius thermometers per group, timer, cold water (less than 10°C.).

SUGGESTED APPROACH:

1. Ask students: At what temperature does water have the greatest density? How could you find out? If you had a large body of water, where would the densest water be? Why? Lead them to the concepts that water is densest at some relatively cold temperature, that the densest water should be on the bottom, and that to find the temperature of the point of maximum density you must measure the temperature on the bottom.

2. Have each group almost completely fill a plastic shoebox with cold water (precool with ice or obtain from refrigerated drinking fountains); add small dyed ice cubes so that they make a layer about 2 cm thick; suspend three thermometers so that one is in the ice, one is near the middle depth, and one is just above the bottom of the shoebox.

3. Temperature readings should be taken every 30 seconds and continued until several identical readings are observed.

4. Plot temperature vs. time curves, for each of the three thermometers, on the same graph.

5. Collect class data and lead students in a discussion of the original question: At what temperature is water the most dense? How do you know? To check understanding, you might ask students to predict what would happen if water had its greatest density at 0°C.

6. A demonstration, to show other substances reach maximum density in the solid phase, may be conducted (e.g., drop solid chunks of paraffin into a paraffin melt and observe them sinking to the bottom).

PRECAUTIONS:

1. If it is necessary to add more ice, do so very gently so that the thermal structure is not disturbed.

2. It is necessary to insulate the shoebox from the table top.

3. Once the investigation is set up, students have little to do beyond reading the thermometers for a relatively long period of time; it is advantageous to provide some other simultaneous activity.

4. The paraffin demonstration should be tried before class time to determine if it will work.

TYPICAL RESULTS:

Provided the water is not shaken or stirred, data should not vary more than ±1C° from 4°C.

MODIFICATIONS:

1. Repeat the procedure using sea water, or have one group of students simultaneously use sea water.
2. Do as a demonstration using a 5-gallon aquarium.
3. If it is impossible to obtain a sufficient quantity of dyed ice cubes, add a few drops of food coloring to the surface several minutes after the investigation has begun. Be sure to provide a control to show that it is not just the density of the dye which causes it to go to the bottom.
4. Suspend a plastic bag filled with water and sealed in a freezer and make periodic observations to determine where freezing occurs first.
5. Use a florence flask filled completely with water and fitted with a two-hole stopper. A thermometer and small bore tubing should be inserted in the stopper. As the flask of water is cooled, the volume, as indicated by the water level in the small bore tube, will decrease. A minimum volume should be observed at about 4°C.

REFERENCES:

Our Planet in Space, pp. 252-255

I-B-1b: VARIABLE DENSITY OF WATER

QUESTION:

How can properties of the environment be measured?

INTRODUCTION:

Have you ever noticed what happens to the temperature of water in a lake as you go deeper into it? Why should the deep water be colder? Where would you find the coldest water of all? Where would you find the densest water? How could you find out at what temperature water has the greatest density?

OBJECTIVES:

When you finish this investigation, you should be able to:

1. collect, graph, and interpret temperature data.
2. describe the relationship between temperature and water density.

METHOD:

1. Fill a plastic shoebox with very cold water and add enough small ice cubes to make a layer about 2 cm. thick. Suspend three thermometers so that one is in the ice layer, one is near the middle depth, and one is just above the bottom.
2. Read each of the thermometers every 30 seconds and record the temperatures. Do not move the thermometers! Continue the readings until the temperatures appear stable.
3. Make a graph of temperature vs. time for each of the three thermometers. Develop all three graphs on the same set of axes.
4. Compare your graphs and data with those of other students.

QUESTIONS:

1. What happened to the colored water from the melted ice cubes? Why?
2. Compare the bottom temperature with (a) the original temperature and (b) the surface temperature after 1, 5, 10, and 20 minutes. Do these comparisons change with time? Why?

(B-2.14) 3. What pattern were you able to infer for the variable density of water?

4. Why doesn't water at the bottom of a deep lake freeze?

5. What would be some of the consequences if the pattern of variable density of water was similar to that of other substances?

(B-2.13) 6. How does the variable density of paraffin wax compare to water?

topic II

TOPIC II - THE CHANGING ENVIRONMENT

How Changeable Is Our Environment?

Time Emphasis: 5 days

TOPIC OUTLINE

INVESTIGATION		LTI - #1	LTI - #2	LTI - #3	A-1a	C-1a	C-1b	LTI - #4	LTI - #5	LTI - #6	LTI - #7	LTI - #8	LTI - #9	LTI -#10	LTI -#11	LTI -#12	LTI -#13	LTI -#14
Estimated Time (Periods)					1	.5	.5											
A. The nature of change																		
A-1 Characteristics of change																		
		How Can Changes Be Described?																
A-1.1 Occurrence of events	A-1.11																	
	A-1.12																	
	A-1.13																	
A-1.2 Frames of references	A-1.21																	
A-1.3 Rate of change	A-1.31																	
	A-1.32																	
A-1.4 Cycles-noncycles	A-1.41																	
	A-1.42																	
A-1.5 Predictability of change	A-1.51																	
A-1.6 Occurrence of change	A-1.61																	
B. Energy and change																		
B-1 Relationship between energy and change		*What Is the Relationship of Energy to Change?*																
B-1.1 Energy flow and exchange	B-1.11																	
	B-1.12																	
C. Environmental change																		
C-1 Man's influence on the environment		*How Have Man Modify the Environment?*																
C-1.1 Environmental balance	C-1.11																	
	C-1.12																	
C-1.2 Environmental pollution	C-1.21																	
	C-1.22																	
	C-1.23																	
	C-1.24																	

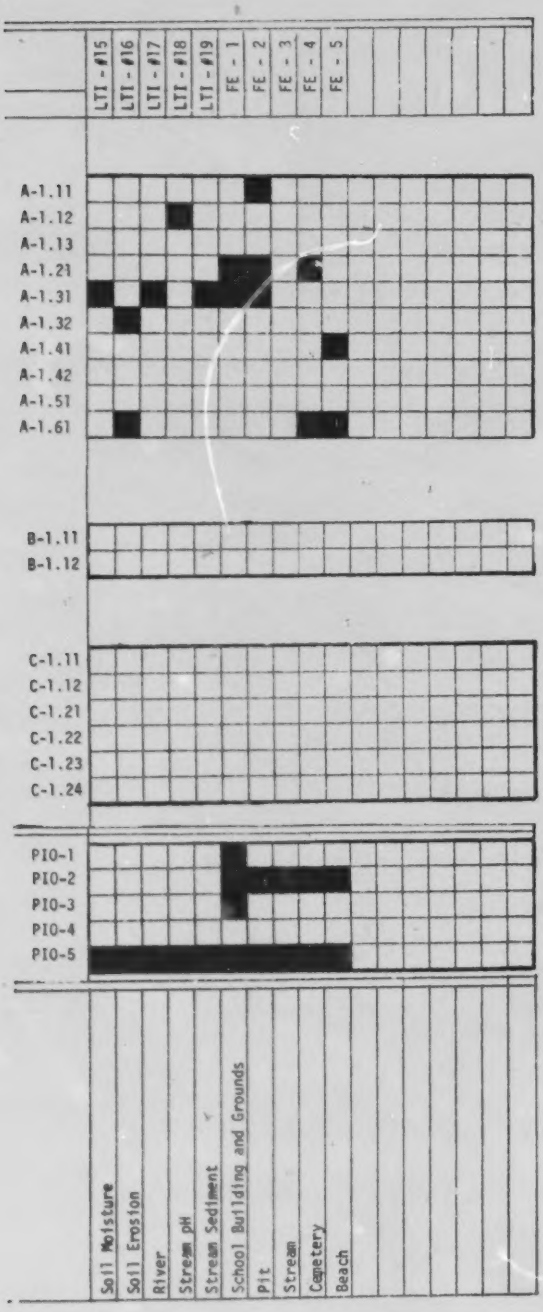
PROCESS OF INQUIRY OBJECTIVES

Mathematical Skill	PIO-1																	
Measurement Skill	PIO-2																	
Creating Models	PIO-3																	
Analysis of Error	PIO-4																	
Data Analysis	PIO-5																	

Multimedia: Check Multimedia Section of Supplement for reference to this topic

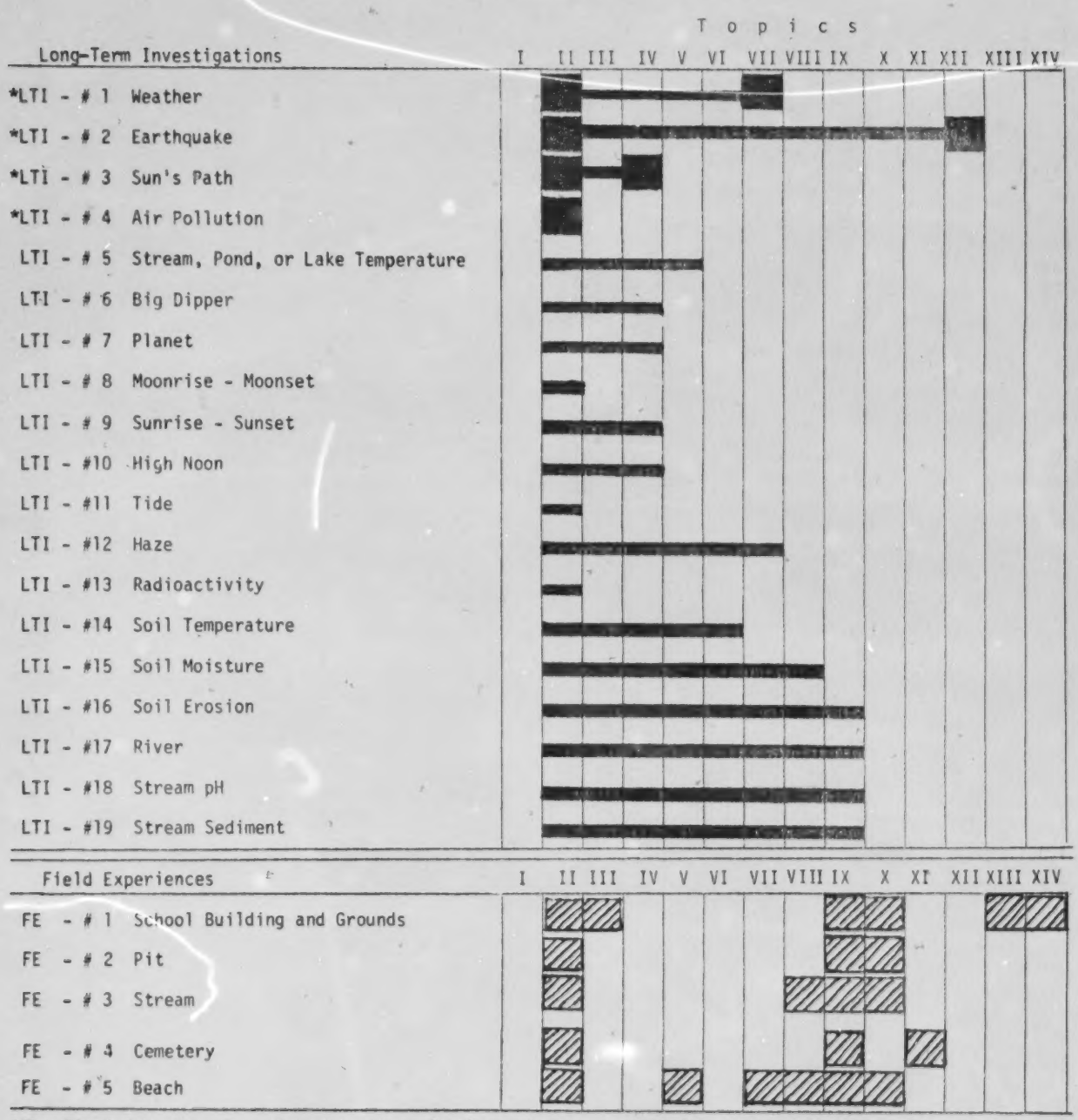
Weather Watch	Earthquake Watch	Sun's Path Watch	Sunspot Analysis	Roadside Pollutants	Air Pollution - Human Mortality	Air Pollution Watch	Stream, Pond, or Lake Temperature	Big Dipper	Planet	Moonrise-Moonset	Sunrise-Sunset	High Noon	Tide	Haze	Radioactivity	Soil Temperature

TOPIC II - THE CHANGING ENVIRONMENT (continued)



MATRIX FOR

LONG-TERM INVESTIGATIONS AND FIELD EXPERIENCES


Topics
Long-Term Investigations
I II III IV V VI VII VIII IX X XI XII XIII XIV
*LTI - # 1 Weather
*LTI - # 2 Earthquake
*LTI - # 3 Sun's Path
*LTI - # 4 Air Pollution
LTI - # 5 Stream, Pond, or Lake Temperature
LTI - # 6 Big Dipper
LTI - # 7 Planet
LTI - # 8 Moonrise - Moonset
LTI - # 9 Sunrise - Sunset
LTI - #10 High Noon
LTI - #11 Tide
LTI - #12 Haze
LTI - #13 Radioactivity
LTI - #14 Soil Temperature
LTI - #15 Soil Moisture
LTI - #16 Soil Erosion
LTI - #17 River
LTI - #18 Stream pH
LTI - #19 Stream Sediment
Field Experiences
I II III IV V VI VII VIII IX X XI XII XIII XIV
FE - # 1 School Building and Grounds
FE - # 2 Pit
FE - # 3 Stream
FE - # 4 Cemetery
FE - # 5 Beach

*The first four Long-Term Investigations (LTI) are found as complete write-ups in the Supplement under the topics as indicated by the blackened-in matrix (i.e. Weather Long-Term Investigation (LTI-#1) is written up in Topics II and VII. The remaining investigations (#5 through #19) do not appear as write-ups.

It is suggested by the bold horizontal line in the matrix that a Long-Term Investigation should be started in topic II and the results of that investigation may be used to reinforce understandings in a topic at the end of the line (i.e. Soil Temperature Investigation (LTI-#14) is started in topic II and may be concluded with specific understandings in topic VI).

Partial shading in the Matrix for Field Experiences indicates topics containing understandings that may be realized by that field experience.

LONG-TERM INVESTIGATIONS

These investigations can be started in Topic II and continued until appropriate end points in later topics as indicated in the matrix for "Long-Term Investigations and Field Experiences" sheet. Some are suitable as individual projects, others could be group or class projects. The teacher can evaluate each to decide which are appropriate for his class, the school location, or geographic position of the community.

1. *Weather

2. *Earthquake

3. *Sun's Path

4. *Air Pollution

5. Stream, Pond, or Lake Temperature:
   Observe and measure surface temperatures or temperatures at various depths. Readings can be taken weekly.

6. Big Dipper:
   Observe and measure the angle of tilt of the handle stars each evening at the same time. Readings could be taken weekly.

7. Planet:
   Observe the positions of planets in terms of their direction and angle of elevation, or relative to the star field background. Readings could be taken as frequently as twice a week. Specific planets whose motions are particularly interesting include Venus and Mars.

8. Moonrise - Moonset:
   Same procedure as sunrise - sunset. This can also be expanded to include a full moon investigation. The readings for the full moon investigation should be taken a few days before to a few days after full moon.

9. Sunrise - Sunset:
   Observe and measure the position and time of sunrise and sunset. Readings can be taken as frequently as twice a week.

10. High Noon:
    Observe and measure the elevation of the sun at its highest point. The local standard time should be noted for each reading. Readings can be taken twice each week.

11. Tide:
    Observe and measure high and low point of the tides. Readings should be taken daily. Students may team up so that one measures a high and the other measures a low tide.

12. Haze:
    Observe and measure the visibility to determine the extent of haze. This can be done in conjunction with the weather investigation. Readings can be taken daily.

13. Radioactivity:
    Observe and measure the amount of radioactivity, by the number of particles trapped on an air filter. Use a fiber glass filter in a Buchner funnel which has been fastened to a vacuum pump. Place funnel outside and pump for 3-5 hours. Place the filter on a sheet of black and white Polaroid film (ASA 3000). The particles will show as bright spots. Readings can be taken weekly.

14. Soil Temperature:
    Observe and measure temperatures on the surface and at 10-cm. intervals down to 1 meter. Readings can be taken daily.

15. Soil Moisture:
    Observe and measure amounts of moisture by removing and drying samples of soil at selected locations. Readings can be taken weekly. Electrical resistivity could also be used as an indicator of moisture.

16. Soil Erosion:
    Observe and measure a fresh road cut, pile of soil, or other exposed soil surface for the effects of erosion. Readings can be taken twice a week.

17. River:
    Measure the stream flow in a stream by constructing a weir or use a spillway. Other methods can also be employed to determine the discharge. Readings can be taken daily.

18. Stream pH:
    Measure the pH of a stream. This can be done in several ways. Students can measure the pH of several points at the same time, or an analysis of the pH at one point can be made over a period of time. Readings in this case can be taken weekly. Caution: pH paper may not be sensitive enough.

19. Stream Sediment:
    Measure the amount of sediment being carried by a river in suspension. Readings can be taken twice a week or more frequently depending on the circumstances.

Easy

LTI #1: WEATHER LONG-TERM INVESTIGATION

QUESTION:

How can changes be described?

MATERIALS:

Rain gauge, wind gauge, barometer, sling psychrometer, maximum-minimum thermometer (optional), cloud code chart, weekly U.S. weather map, instructions for climatological observers (circular B). The last three items can be obtained from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C., 20402; order, (a) Cloud Code Chart No. 30.22: C 62/2/958, 10¢, (b) Instructions for Climatological Observers, Circular B, No. C 30 4:B/962, 50¢, (c) Weekly Weather Map, subscription rate $4.50 per year. Be sure to include payment (not purchase order) with your order.

SUGGESTED APPROACH:

1. The teacher should refer to the concluding investigation VII-A-1a before beginning this LTI.
2. Discuss the purpose of this investigation, how to handle and use the instruments, ways of recording data, and how responsibility for daily measurements will be distributed and rotated. The purpose is to obtain sufficient data so that identifiable patterns can be found and analyzed in topic VIII.
3. Following the introductory investigation, allow groups of students about 5 minutes each day to make and record their weather observations.

PRECAUTIONS:

1. Most of the instruments used are somewhat fragile.
2. Periodically check measurements, dew point calculations, and graphing for accuracy and consistency.
3. Guard against investigation becoming routine and meaningless by periodically having the students look for patterns among weather variables and, on the basis of these, make predictions about future weather. Tie in local data with U.S. weather map.
4. Develop some way of obtaining data, especially temperature and pressure, over weekends and vacations; thermographs and barographs are the best means but newspaper reports and home readings do work.
5. Freezing of the wet bulb on a psychrometer can cause trouble later on in the Watch. It may take 10 minutes to get a reading with the dry bulb below 0°C. (Remove sleeve from wet bulb and moisten bulb with damp tissue paper.)

TYPICAL RESULTS:

In the beginning, students may have difficulty taking accurate readings but they quickly become quite professional about it.

MODIFICATIONS:

1. Data may be kept individually or as a class on a large wall chart.
2. Many of the instruments can be homemade. If possible, these should be checked for reliability against commercial instruments.
3. Once students begin to recognize patterns and make predictions based on these patterns, they could make predictions for the whole school.

REFERENCES:

Investigating the Earth, pp. 26-27, Teacher's Guide, pp. 51-55, 65.
Our Planet in Space, pp. 226-231, 242-246, 258, 264-279.

LTI #1: WEATHER WATCH

QUESTION:

How can changes be described?

INTRODUCTION:

Weather is one of the most talked about subjects and one of the most puzzling. You can describe the weather right now, but can you predict what it will be tonight, tomorrow, or next week? To be able to predict the weather you will need to know what weather patterns exist in your area. This can be accomplished by collecting weather data over a long period of time.

OBJECTIVES:

When you finish this investigation you should be able to:

1. make accurate daily measurements of temperature, barometric pressure, wind speed and direction, dew point, precipitation, cloud cover and type.
2. record the collected data in a well-organized table.
3. graph the collected data against time.

METHOD:

1. Every day at the same time, measure the air temperature, barometric pressure, amount of precipitation during the last 24 hours, cloud type and percentage of cover, wind speed and direction, and dew point. You won't make all these measurements yourself; the job will be shared by other students in the class.
2. Record the data on a table or graph-chart.
3. After you have collected data for about 2 weeks, begin to look for patterns and try to relate your data to the U.S. weather map.

QUESTIONS:

(A-1.11) 1. Describe the changes which you are able to observe taking place in the atmosphere.

(A-1.61) 2. Describe what you would consider the most natural state of your atmospheric environment. Would it be static or changing?

(A-1.41) 3. Describe the cyclic nature of the changes observed.

(A-1.51) 4. After observing the changes in the atmosphere for a few weeks, attempt a prediction of future events.

Supplementary Sheet

LTI #1

MODEL DATA SHEET FOR WEATHER WATCH

Date Time							
Air Temperature in °C. 40							
30							
20							
10							
0							
-10							
-20							
-30							
Atmospheric Pressure in mb. 1040							
1030							
1020							
1010							
1000							
990							
Wind direction, speed, and sky cond. Cloud type Weather							
Precip. in inches 0.5							
0.3							
0.1							

Adapted from ESCP

Easy

LTI #2: EARTHQUAKE LONG-TERM INVESTIGATION

QUESTION:

How can changes be described?

MATERIALS:

World map, colored pins (100 each of 3 colors or large acetate sheet and felt pens - 3 colors) data cards (obtained from U.S.Coast and Geodetic Survey (Seismology Division), Washington Scientific Center, Rockville, Maryland, 20850; request Preliminary Determination of Epicenters).

SUGGESTED APPROACH:

1. Teacher should refer to concluding investigation XII-A-2a before beginning this LTI.
2. Discuss with the students some natural changes that occur on the earth and how these changes can be described. Include in your discussion the fact that earthquakes represent very dramatic changes.
3. Point out that earthquakes occur often and can be described in terms of location on and depth beneath the earth's surface. Ask how a continuous record of these events might be recorded so as to provide for easy interpretation.
4. Have groups of two students each plot on a wall map data of a few earthquakes.
5. Have one or more groups continue this exercise on a once or twice per week basis until the class is ready to analyze the data in topic XII.

PRECAUTIONS:

If Pacific Ocean-centered maps are used, the students may find longitude plotting confusing. The map will have both east and west longitude plotted on the same side of the prime meridian.

MODIFICATIONS:

Individual maps could be used in place of one wall map.

LTI #2: EARTHQUAKE WATCH

QUESTION:

How can changes be described?

INTRODUCTION:

Many destructive natural changes occur on the earth. Probably one of the worst in terms of human experience is the earthquake. In 1964, the Alaskan earthquake caused tremendous damage and in 1969 it was the Peruvian earthquake; however, a tremendous number of unpublicized less destructive earthquakes occur every month.

OBJECTIVE:

When you finish this investigation you should be able to:

1. plot location and depth data, for earthquakes, on a world map or globe.

METHOD:

1. Devise and use a system for plotting location and depth data for earthquakes on a world map.

2. Continue plotting earthquake data, during your free time, until your teacher asks you to stop.

QUESTIONS:

(A-1.13) 1. Describe some of the changes which might occur during an earthquake.

(A-1.61) 2. Would you describe the change that occurs during an earthquake as being natural? Explain.

(A-1.21) 3. What frames of reference would you use to describe an earthquake?

(A-1.51) 4. Describe the possibility of determining in advance where and when an earthquake will occur.

Easy

LTI #3: SUN'S PATH LONG-TERM INVESTIGATION
(refer to investigation IV-A-1C)

QUESTION:

How can changes be described?

MATERIALS:

Transparent hemisphere mounted on cardboard square, grease pencil, or water soluble pens.

SUGGESTED APPROACH:

1. This investigation is best accomplished with a student grouping of two.
2. This investigation requires multiple readings throughout the same day and should be done as close to September 20 as possible.
3. Follow the directions on the student sheet to plot the position of the sun, at various times of the day, on the plastic hemisphere.
4. One of the hemispheres should be selected as a master sphere for the class and stored in a safe place. Subsequent readings should be made and recorded on the master sphere (i.e., October 20, November 20, December 22, etc.)

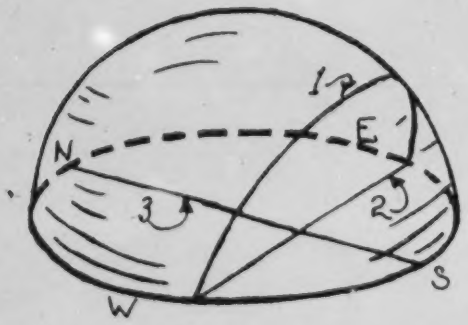
PRECAUTIONS:

1. Baseboards on which the hemispheres are placed must be oriented the same way for successive recordings. Line up a marked edge of the baseboard with a marker line on the sidewalk or ground, as shown in the figure on the student sheet. Be sure surface is horizontal.
2. The hemisphere must be placed so that buildings, trees, and other obstructions will not cut off the sun's rays during the time recordings are made.
3. In the event of a cloudy day or if cloudiness develops during a day on which readings have begun, see an alternate procedure in "Modifications."

TYPICAL RESULTS:

The diagram below represents a typical example of results that students should attain.

Additional construction lines are shown which can be used to complete the analysis.



1. Sun's path extended to the horizon
2. E-W line connecting the sunrise-sunset points which is parallel to an east-west line (on September 20 and March 20 it would be the E-W line)
3. A line perpendicular to the E-W line which is the true N-S line

MODIFICATIONS:

1. In the event that overcast skies exist on the day chosen for this investigation, it may be possible to plot points using the following method: Have a student stand facing the hemisphere with his back to the sun. By moving toward or away from the hemisphere he can select a position where the bright spot (cloud covered sun) reflected from the hemisphere and the reflection of his head line up. At that point the center of the hemisphere (x), the point on the hemisphere, his head, and the sun are in line. A second student should mark that spot on the sphere with the grease pencil.

2. Magnetic declination can be found by dropping a vertical line from the Zenith through the apex of each curve to establish a true N-S line and then measuring the angular difference between this line and the magnetic compass bearing.

REFERENCES:

Investigating the Earth, pp. 27, Teacher's Guide, pp. 56-57.

LTI #3: SUN'S PATH WATCH

QUESTION:

How can changes be described?

INTRODUCTION:

Man has always had a great interest in the sun and for some men it has represented a God. In this investigation you will have an opportunity to examine more closely the apparent movement of the sun and look for evidence of change.

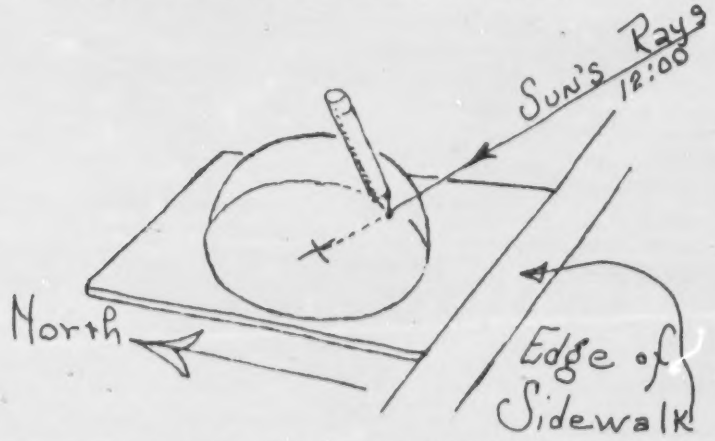
OBJECTIVES:

When you finish this investigation you should be able to:

1. construct an arc on the transparent hemisphere representing the apparent sun's path across the sky on a particular day of the year.

METHOD:

1. At various hours of the day, including solar noon, plot the positions of the sun on a plastic hemisphere by placing the cardboard along the line on the ground and placing the grease pencil so that its shadow falls on the "x" in the center of the cardboard (see diagram below). Be sure to record the time.



2. When all of the points, taken at various times of the day, have been plotted on the hemisphere, connect them so as to illustrate the path the sun followed on that particular day.

QUESTIONS:

1. Describe the apparent path followed by the sun across the sky.

(A-1.31) 2. How could you describe the sun's changing position across the sky?

(A-1.51) 3. Predict the sun's behavior for tomorrow.

(A-1.41) 4. How can you best describe the sun's daily behavioral pattern over an extended period of time.

Easy

LTI #4: AIR POLLUTION LONG-TERM INVESTIGATION

QUESTION:

How does man modify the environment?

MATERIALS:

Variation #1 - Plastic Clorox bottle (1/2 gal.), knife, support post (3 ft.), glass slides, clear grease (i.e., vaseline), microscope.
Variation #2 - Jar (1 gal.), support post (3 ft.), sticky white paper, spray clear lacquer.
Variation #3 - Good quality (15 denier) nylon hose, cardboard slide mounts (2 in. X 2 in.), projector, ringstand and clamp (2 required).

SUGGESTED APPROACH:

1. Discuss briefly with students prior to beginning the investigation some of the current problems raised by environmental pollution. Recent articles in newspapers and magazines should be helpful.

2. You may wish to have students perform only one of the three suggested variations.

3. After completing the investigation a more thorough discussion of pollution can be conducted. References to local problems are particularly desirable. This long-term investigation applies most directly to topic II, however, the concluding discussion will have to be held during a future topic, to which it may not apply.

   Variation #1: Students should compare their location counts at different locations by referring to Supplementary Sheet #1 (Ragweed Pollen Survey).

PRECAUTIONS:

1. The investigation should be conducted sometime within the interval from mid-August to mid-September when ragweed pollen is wind-blown. In the Supplementary Sheet #1, for a municipality, the yearly index number is several times greater than the average weekly pollen count per square centimeter.

2. Care must be taken to see that any materials to be exposed have not been previously contaminated.

3. This long term investigation does not have a concluding investigation in a later topic. When completed, the teacher must provide time during which the data can be analyzed.

BACKGROUND INFORMATION

Variation #1

Hay fever, caused primarily by pollen from ragweed, affects more than one million persons in New York State, making it a major public health problem.

Variation #3

Dirty air costs each person in New York State $65 a year according to the New York State Department of Health. Clothes get dirtier and wear out faster. In this investigation, students will be made aware of the effects of air pollution on a common item of clothing.

LTI #4: AIR POLLUTION WATCH

QUESTION:

How does man modify the environment?

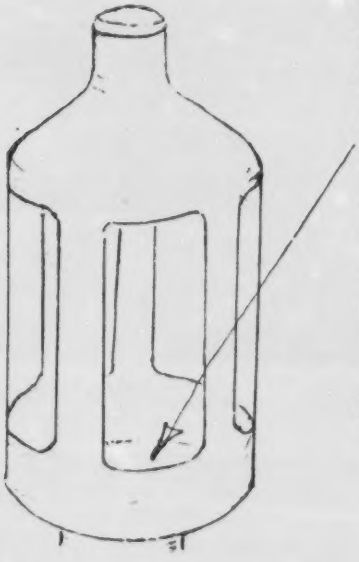
INTRODUCTION:

Much attention has been given in recent years to the problems associated with air pollution. There may be present in the air a high content of pollutant material without its presence being easily detected. Nor do we yet know about the long range effects of some air pollutants.

METHOD:

Variation #1 (Pollen Sampling)

Make a pollen sampler by cutting a Clorox bottle as illustrated. Nail it to one end of the support pole or fence post and place the mounted shelter in an area free from obstructions.



Place a greased slide inside the bottle.

The vertical distance from the slide to the upper cut portion of the jar should be 6 inches. The upper part of the jar provides protection from rain and particulate fallout.

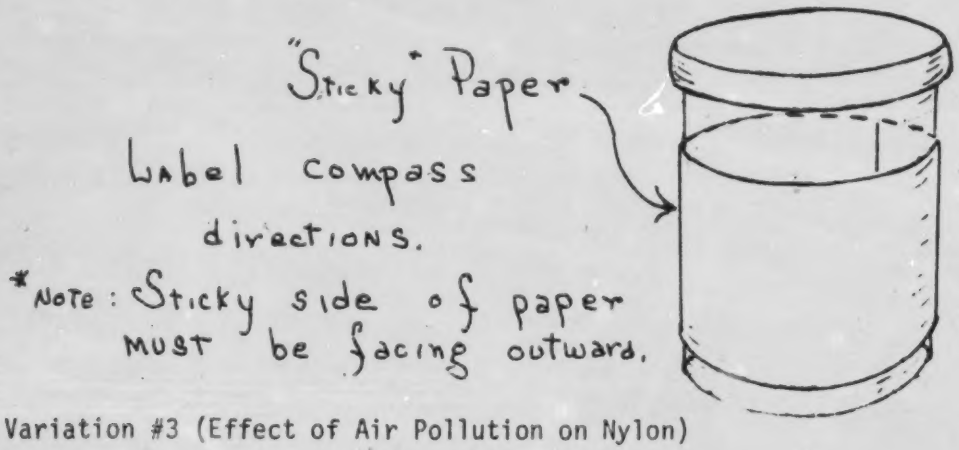
After a 24-hour exposure examine the slide under 100X magnification. Count the pollen per square centimeter.

Variation #2 (Particulate Sampling)

Make a wind-blown particle sampler by wrapping a strip of sticky white paper completely around the jar as shown.

Mount the jar on the support pole outdoors in an area free from obstructions. Expose for 1 week then spray the sticky paper with clear lacquer to preserve the particles in place. Mark the compass directions on the paper. Compare the concentration of particles at each compass point with the accompanying standard

photographs. Estimate the number of particles collected per square inch from each direction.



Variation #3 (Effect of Air Pollution on Nylon)

Stretch a 2 in. X 1 in. piece of nylon hose over one-half of a cardboard slide mount. Glue it in place, and then glue the second slide mount to it, completing the slide mount. Prepare a second sample in the same manner. Place both samples on the school roof in a horizontal position. Leave one sample exposed for 30 days, the other sample for 90 days. At the end of each exposure period, examine the sample for broken threads. Place a sample inside as a control sample. Observe and record the number of broken strands for each sample.

QUESTIONS:

Variation #1

(C-1.21) 1. Why is it correct to refer to pollen in the air as pollution?

(C-1.22) (C-1.23) 2. Describe the source of these pollutants.

(C-1.24) 3. Would the pollen count be higher or lower in the winter as compared to the summer-fall season?

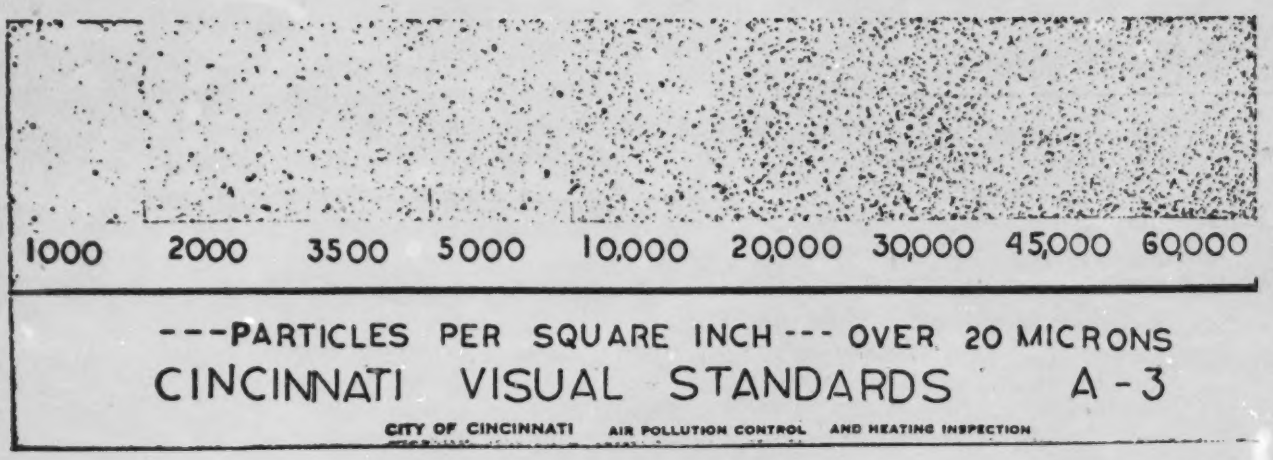
Variation #2

(C-1.22) (C-1.23) 1. What is the source of the particulates for each compass direction?

Variation #3

(C-1.21) 1. Describe the effects of air pollution on nylon.

SUPPLEMENTARY SHEET #2
(PARTICULATE MATTER STANDARD SHEET)



NOTE: The reproduction of the standard particles per square inch is not a true reproduction of the photographic standards, and should not be used for measuring or estimating the number of particles collected per square inch of sticky paper.

Introduction to Field Experiences

Each of the field experiences represents an attempt to extend the process of inquiry beyond the classroom. The field experiences are organized around the characteristics of the possible sites rather than a particular syllabus topic. The accessibility of the site should determine whether it is most desirable to deal with several problems on a single visit, or to make multiple visits to deal with the problems as they relate to the particular syllabus topics. If a student has carried out an investigation related to one of the problems for study as part of a long-term watch, the teacher may wish to use that student as a resource person or leader when the appropriate field experience is used. The field experiences have been keyed to the investigations—understandings matrix for the specific topics.

The format of the field experiences sheets includes three columns as follows:

Problems for Study: Each problem constitutes, in effect, a separate investigation and can be adapted by the teacher to fit the local situation. The characteristics of the site may suggest additional problems which the teacher can identify by an advanced visit.

Suggested Approach: The suggested approach contains ideas which can be translated into student procedures. Where a suggestion relates closely to one of the in-class investigations in the supplement, appropriate reference has been made. Students should be encouraged to devise their own procedures for problems which have been identified by either the teacher or the student. An advance trip by the students can help to orient them in planning procedures. If this is not possible an alternative would be to show pictures and to describe the site. Preplanning is essential since equipment needs must be anticipated, and the time factor should be determined.

Equipment: The equipment suggestions should serve only as a guide. The procedures to be employed should determine the actual equipment needs. The teacher should strongly encourage the students to plan for equipment needs so that the field time can be most efficiently spent.

Student Questions: At the end of each field experience are student questions which correspond by number to the Problems for Study. They are intended to be used as leading questions and can be added to or modified for student use as the teacher sees fit. They may also be used as introductory questions to initiate the Problems for Study.

N.B. *Before attempting any field experience or field trip:*

1. *obtain permissions for access where necessary.*
2. *determine the school policy for field trip activities regarding student permission slips, means of transportation, and insurance coverage.*
3. *identify students with handicaps which may limit their participation.*
4. *obtain simple first aid equipment and be familiar with simple first aid practices for the occasional minor mishaps.*

Location possibilities: The school building and grounds have been chosen as the first field resource because of the lack of transportation problems.

Possible Problems for Study	Suggested Approach	Equipment
1. **Observation**	1. See Investigation I-A-1b: Puddle Puzzle.	None
2. **Altitude of the sun**	2. Using the shadow cast by a stick it is possible to indirectly measure the angle of the sun's rays. (See also HIGH NOON WATCH and Investigation III-B-1a.)	Student astrolabes, or large protractor, or devil level Measuring tapes or meter sticks
3. **Reading and observation of barometric pressure differences**	3. Barometric pressure readings should be taken at each floor level. The following are possible outcomes of this investigation: skill in instrument reading, change occurring through space, the relationship between altitude and pressure, and the possible cause of barometric pressure. (Caution: If a mercury barometer is used it is suggested that you tap the column before taking a reading.	Barometer (mercury type works best) Tape measure
4. **Weathering**	4. Evidence of weathering may be obtained by observation of bricks, concrete, metal flooring, paint, rock (as used in window ledges, steps, or base), and mortar between bricks. If parts of the building were constructed at different times, have students look for evidence of differential weathering. Students may also look for evidence of weathering resulting from varying exposures to wind, sun, and precipitation.	Hand lens Metric rulers
5. **Erosion**	5. Stair treads in all but the newest schools show such signs of wear as: rounding of edges, polish on metal treads, and uneven surfaces. Students can speculate on the possible causes of differential erosion on the various parts of a particular staircase or between two staircases (For example, there tends to be less erosion on upper stories, back stairways, and on the extreme inside edges of treads.)	
6. **Order of events**	6. If there is construction in the area, there are likely to be piles of scrap lumber. This lends itself to a study of the sequence of events that resulted in forming the pile. Students can dismantle the pile in a "pick-up-sticks" fashion, marking each piece for identification. In addition, sun-bleaching or grayness resulting from weathering might be evidence of overturning or interruption of deposition. Bushes and shrubs may act as "intrusions" which have continued to grow as the pile accumulated.	Gloves Tags Felt tip marker
7. **Contouring a hill**	7. Locate one student at the base of a hill. Have him balance a carpenter's level (horizontally) on a vertically positioned meter stick. After levelling the carpenter's level he should be able to sight along its top edge while rotating it in a horizontal plane. His line of sight should traverse the hillside, passing all points with an elevation one	Meter stick Stakes Hammer Carpenter's level or transit

Possible Problems for Study	Suggested Approach	Equipment

meter higher than the point on which the meter stick is resting. Have students locate themselves at approximately equal intervals along the hillside. The student with the level can then direct them up or down the hillside until their feet are on his line of sight, at which point a stake can be driven. When finished, a line of stakes should follow the contour of the hill. The instrument man can then move uphill to one of the stakes and the operation can be repeated. After each sequence another row of stakes following a contour one meter higher than the previous will result.

If at least one set of stakes are positioned in a straight line up the hill, their horizontal position can be measured and a profile constructed. This could be expanded into a contour mapping exercise by determining the horizontal position of all stakes.

Student Key Questions:

1. See questions for Investigation I-A-1b.

2. What is the size of each of the angles? Which of these angles is measuring the altitude of the sun? Explain, using a diagram to help. (To be used with Investigation III-B-1a.)

3. What was the barometric reading at each of the floor levels? What was the change in height between each floor? What was the total change from top to bottom? What is the relationship between barometric pressure and elevation? What is the fundamental cause of atmospheric pressure?

4. What evidences of weathering can you observe in the materials of the building? What factors seem to influence their rate of weathering? Starting with those that weather fastest, make a list of building materials that seem to be weathering. How can you measure the amount of weathering on one type of building material? How does the amount of weathering of this material compare for all parts of the building? What factors do you think may have caused the different amounts of weathering?

5. Knowing the date of erection or remodeling of the school building, how can the rate of wearing away of stair treads be calculated? How does the amount worn away compare for the different parts of any one tread? How does it compare for different treads on the same set of stairs? How does it compare for treads on different staircases? How can school traffic patterns be inferred from the amount of wear on the stairs?

6. From your observations, what can you infer about the order in which the pile accumulated? What are the limitations of the method you used to determine the order in which the scraps were put on the pile? What assumptions did you have to make? What evidence did you find that some of the boards had undergone natural weathering? How much of the surface was bleached or weathered? What does this indicate about the sequence of events as the pile formed? How might a geologist use similar techniques in the field to determine the sequence of events shown by a series of rock layers?

7. Describe what is meant by contouring a hillside. How can the instrument-man's line of sight be described? What points on the hillside will it intersect? What measurements should you have before attempting to prepare a profile of an area? A contour map?

Location possibilities: Building site excavations, gravel pits

Possible Problems for Study	Suggested Approach	Equipment
1. Evidence of change a) taking place over an extended time b) as the site is visited on a single trip	1. Students should make observations of evidence that suggests change. If the site can be revisited, students can record measurements or take photographs to study change over a period of time. It may be helpful to get students started with a question such as: "What kinds of observations suggest change?"	Camera
2. Weathering	2. Students should look for evidence of weathering, such as sizes and orientation of particles. Other observable factors related to weathering might include: plant life, animal traces, differential weathering of single particles or of different rock types, and evidence of soil formation.	Hand lens Shovels or trowels Dilute HCl; 10:1
3. Soil profiles	3. Students can test different sections of the pit at various levels for such things as mineral composition, particle size, the presence of $CaCO_3$, topsoil, colloids and humus.	Hand lens Dilute HCl; 10:1 Shovels or trowels Water Test-tubes
4. Deposition and sedimentation a) as viewed on side walls b) at the base of slopes c) graded bedding	4. Students can look for evidence of layering. They should compare the material within the layers and between layers in terms of particle composition, orientation, shape, and size. In addition, students should be encouraged to look for other evidence which provides clues as to whether the material is transported or residual. From the evidence collected (including observations from problems 1, 2, and 3) students should develop a model of the sequence of events that occurred in the area.	Hand lens Dilute HCl; 10:1 Shovels Instrument for measuring angle (Devil level, Brunton compass, or carpenter's level) Measuring tapes

Student Key Questions:

1. Which of your observations suggest that a change has occurred? What events might have caused these changes? What changes have occurred between visits? What might have caused these changes?

2. What was the cause of the weathering of the material in the pit? What evidence suggests that the materials in the pit have undergone differential weathering? What could have caused this?

3. How many different soil layers are present? What evidence can be used to determine how long the process of soil formation has been going on in this area? From your observations, how do the layers compare in terms of particle composition and size?

4. How do the materials in the various parts of the pit compare in terms of particle composition? particle size? particle shape? particle orientation? Which agents of erosion and/or deposition have been active in this area? What evidence suggests that the material present is residual? is transported? What possible sequence of events could have occurred in the area that could account for the composition of the pit?

Location possibilities: Creek, construction site, drainage ditch, gutters

Possible Problems for Study	Suggested Approach	Equipment
1. Stream velocity	1. Students can determine the velocity of a stream with floating markers such as styrofoam balls or matchsticks placed at strategic points in the stream: a) across the stream bed b) across the stream at places of varying gradient c) outside and inside of a curve See Investigation IX-B-2a for techniques for determining stream velocity.	Stop watch or watch with sweep second Markers (floating) Measuring tapes
2. Gradient	2. Careful choice of a stream where gradient differences are great enough to be calculated is essential. Have two students move to positions along the stream bank holding the ends of a 100 ft. piece of string. Have them pull the string until it is taut and hold it just above the water level. Have a third student hook a line level near the midpoint of the string. This student should then instruct the student at the appropriate end to raise his end until the string is level. A fourth student can measure the height to which the string has been raised.	Meter stick Line level
3. Discharge	3. The profile of the stream bed can be determined by measuring the depth at various intervals across the stream. The cross-sectional area can be estimated from the profile by averaging. The average stream velocity should be determined. An estimate of the discharge can be obtained from the product of the cross-sectional area and the velocity. The smaller the stream, the more immediate will be the effects of run-off due to rains. Therefore, measurements before and following storms will be more noticeable than on larger streams.	Meter stick or measuring tape String (with markers attached for measuring depth) Markers (floating) Stop watch
4. Erosional features	4. With careful observation, features such as meanders, potholes, waterfalls, rapids, cut banks, plungepools, and gorges can be found in small streams as well as large ones. The cause, location, and degree of erosion that was necessary to form the feature should be theorized.	
5. Suspended load	5. In larger streams, water samples can be collected in glass jars at various depths and locations along the stream bed. The jars should be coded and the sample allowed to settle. The amount, type, and size of sediments should be analyzed relative to their depth and positions along the stream. It may also be desirable to collect samples from a given location at different times (e.g., before and after heavy precipitation).	Large-mouthed jars Hand lens Watch Stream map

Possible Problems for Study	Suggested Approach	Equipment
6. Deposition a) order of b) placement in bed c) micro-features such as ripple marks, cross bedding, or graded bedding	6. Features such as sandbars, deltas, alluvial fans, braided streams, and levees can be found both in small and large streams. The cause, location, and degree of deposition that was necessary to form the feature should be theorized. Take samples of bar or delta areas using cores corresponding to the size of the stream. Although less desirable, a soil auger can be used in more compacted areas.	Plastic tube, or lipstick tube, or soil auger Hand lens Stream map
7. Interrelation of stream variables to stream's character	7. By combining the appropriate approaches outlined above, the students should be able to relate the stream's velocity, discharge, and gradient to the nature of the stream bed and the effects of erosion and deposition. N.B. In most, if not all of the above approaches, an excellent teaching aid would be a map of the stream. Its detail would depend upon the nature of the study and the stream. This could be teacher-prepared for a hand-out, student-prepared on site, or a composite of student maps.	
8. Pollution	8. If so desired, and planned in advance, it should be possible to run a chemical analysis for pollutants on site. For additional information regarding techniques see Investigation VIII-A-3a and the sources listed at the end of that investigation. Other excellent sources include: Simplified Procedures for Water Examinations, American Water Works Association, 2 Park Avenue, New York, New York. $6. Simplified Laboratory Procedures for Wastewater Examination, Water Pollution Control Federation, 3900 Wisconsin Avenue, Washington, D.C. $3.	See Investigation VIII-A-3a

Student Key Questions:

1. What is the velocity of the stream at your station? At which station did the stream flow fastest? slowest? What factor(s) do you think were responsible for the difference in stream velocity?

2. What was the stream gradient at your station? At which station was the stream gradient greatest?

3. What are the limitations of the method you used for determining stream discharge? How does the rate vary with change in weather conditions? What is the time delay?

4. What are some possible causes of each of the erosional features you observed? How are these features likely to be affected in the future? Why?

5. How can the similarities and differences in the appearance of the water samples taken at various positions be accounted for at the time they were collected? How do they compare after they have been allowed to settle? How do the samples from different locations compare? Why? How do the samples collected at different times compare? Why?

6. How are the core samples taken at each point related to the stream characteristics at that point?

7. How are each of the characteristics of the stream that you measured related? How are each of the measured characteristics related to other observed characteristics of the stream?

8. For appropriate questions see Investigation VIII-A-3a.

Location Possibilities: Cemetery (preferably one that is long-established)

Possible Problems for Study	Suggested Approach	Equipment
1. Differential weathering on tombstones due to: a) lettering style: etched or raised b) rock type used c) exposure direction d) protection by surroundings e) vertical or horizontal position f) elevation in relation to the surroundings g) exposure time h) man versus nature	1. The nature of tombstones - with their dates - make them ideal for studying weathering rates. A prior visit to the cemetery is desirable so that sections of varying age can be located. (CAUTION: not all death dates reflect the date of erection of the monument.) You might try introducing the problem by asking students what kind of rock, where placed, and/or type of lettering he would choose if he wanted to have an "everlasting" monument. Students can observe individual monuments for evidence of weathering due to surroundings, prevailing weather direction, and exposure of lettering. Pitting, obliteration or obscuring of lettering, rounded edges and loss of polish are examples of evidence of weathering. In comparing the amount of weathering among several monuments, care should be taken to keep the rock type as a constant.	Hand lens Dilute HCl, 10:1 (N.B. use with discretion at base only)
2. Chemical weathering due to lichen, moss, etc.	2. A number of variables in the biochemical realm that affect weathering can often be observed on headstones. Simple plants will grow more abundantly on certain rock types, resulting in a faster rate of weathering. Compass direction and protection (e.g., shaded or sunny) will affect their abundance. One factor often overlooked is the weathering due to plant acids at different heights on the stone. Tombstones tend to weather faster near the base if grass is present.	Hand lens Magnetic compass
3. Hillside creep indicated by inclination of headstones	3. If a cemetery or part of a cemetery is on a relatively steep hillside, creep may occur. The amount of creep can be estimated by measuring the angular displacement from a vertical position of the headstone. The age obtained from the monument can be used to estimate the rate of creep. If possible, measure the displacement of several tombstones of the same age at different elevations on the hill.	Instrument to measure angle (Brunton, Devil level, astrolabe, or carpenter's level) Meter stick Plumb line String and weight
4. Chronological order of cemetery development	4. By determining the dates on the monuments in each plot it should be possible to construct a map showing the chronological development of the cemetery.	
5. Study of land/soil usage	5. Students can speculate as to why a cemetery was built at this site. If available, students should first be provided with maps showing other cemeteries. This will enable them to look for a pattern. Some of the reasons for placement could be esthetic beauty, good drainage, easily dug soil, near a church, the poorest land available in a farming area, the only land available, or proximity to a settled area. While some of these factors are sociological, many can be woven into an earth science frame of reference.	Topographic maps of area Soil maps of area Aerial photos (not essential) Older maps of area showing growth and development Soil testing kits

FE #4

Student Key Questions:

1. What evidence did you find that the tombstones have undergone weathering? What factors do you think are responsible for variations in the degree of weathering? What effect does each of these factors have on the appearance of the surface of the monument?

2. What relationship, if any, did you find between plant type and rock type? How were the plants distributed on all sides of the stone? What evidence suggests that plants are very important or unimportant agents of weathering for the stones you studied?

3. What is the relationship between age of headstone and angular displacement? What is the relationship between position on the hill and the angular displacement? What is your estimate for the rate of creep?

4. Which part of the cemetery is oldest? youngest? Why do you think the sections were developed in the order suggested by your map?

5. What is the drainage of the area like? What indications are there of the depth of the water table? What is the type of topsoil? What is the underlying soil? What are the underlying rocks probably like? How deep is the bedrock? With the population increasing as it is, do you think that the present use of this land will continue to remain the same?

Location possibilities: Ocean beaches, both tidal and lagoonal; lake beaches; river beaches

Possible Problems for Study	Suggested Approach	Equipment
1. Wind erosion and deposition	1. Look for dunes (stationary or migrating), man-made barriers, distribution of plants, and frosted sand grains.	
2. Origin of beach material	2. Students should examine the composition, size, and roundness of the beach particles, and the percent of shell fragments. A comparison should be made with the materials observed farther inshore. Students should theorize about possible origin of the beach sand.	Hand lens Probe needles Dilute HCl
3. Behavior and nature of waves on water a) motion of waves b) longshore drift	3. Floating markers can be set on the water at intervals in a line perpendicular to the beach. At least some of the locations should be far enough from the shore to be beyond the point where the waves are breaking. The motions of each marker should be described and then compared. In particular, a comparison should be made between the motion of those markers close to shore and those further out. Longshore currents can easily be detected by the motion of the markers close to the beach. Water-marking dye may be used in addition to or in place of the floating markers.	Bright, visible floating markers such as beach balls or large styrofoam balls Rowboat Water-marking dye (non-poisonous)
4. Evidence of tidal zones	4. Look for abrupt or gentle changes in beach slope, changes in composition and size of beach material, and the position of driftwood and/or living organisms such as kelp beds or clam beds.	
5. Comparisons of change in beaches over an extended time	5. Students can attempt to locate beach area features on old topographic maps or photographs, if they are available. If the map or photograph is sufficiently old, many of the features will be altered or missing. Students should be encouraged to theorize as to the causes of the changes. Periodic measurements or photographs can be made as part of a long-range watch in an attempt to determine both the nature of any changes and the rates at which they occur.	Topographic maps Photographs
6. Sea and land breezes	6. This problem requires two visits, one within a few hours of sunrise and the other in midafternoon. Wind speed and direction, air, soil, and water temperatures, and barometric pressure readings should be taken some distance from the shore over the land and, if possible, over the water.	Aneroid barometer Thermometers Hand wind speed indicators Local, recent offshore and inland weather report
7. Man's struggle with the beach	7. Man - in his attempt to maintain a beach in its present condition or alter it to fit his needs - often interferes with on-going natural processes. Evidence for this includes constructing groins or jetties; dredging; erecting wind barriers; planting grasses and shrubs; filling in lagoons; killing natural vegetation; constructing buildings; roads, bridges, and docks. Students should look for evidence of man-made alterations and make inferences as to the effects of these	Topographic maps

Possible Problems for Study	Suggested Approach	Equipment

alterations. In addition they can attempt to project the future of the beach.

Student Key Questions:

1. What features can you observe that suggest wind erosion at this site? wind deposition? Do you think that the net effect of the wind at this site has been destructive? Explain. What has man done at the site to aid these processes? to retard them?

2. How many different kinds of particles did you observe? What is the relative abundance of each type? How much variation did you find in particle size? shape? Where did the material on the beach come from? How did it get there? How does the material at the beach compare with that farther from shore? Why?

3. How does each marker move? How do you account for any similarities and differences in the type of motion and the rate of motion among the markers?

4. What evidence can you see that indicates a change in water level? How many different water levels does the evidence suggest? How are the levels similar? Different? Why?

5. List and observe features along the beach that you can find on your topographic map or photograph. Which of these features, if any, appear to have been altered? How? Which features shown on the map can no longer be found on the beach? What processes might have brought about the destruction or disappearance of these features? What additional changes, if any, would you expect to find if you were to observe the beach several days later? several months later? several years later?

6. How does the soil temperature compare with the water temperature? Why? How does the air temperature over the land compare with the air temperature over the water? Why? Explain the direction wind blows in terms of air pressure?

7. What evidence suggests that man has altered the beach? Which of these alterations has he done to maintain the beach as it is? Which have been done to change the beach to fit his needs? What do you think will be the long-range effect of these alterations?

Easy (1)

II-A-1a: SUNSPOT ANALYSIS

QUESTION:

How can changes be described?

MATERIALS:

Telescope (or binoculars), graph paper, sunspot data (see supplementary sheet).

SUGGESTED APPROACH:

1. For many students, this will be the first time they will observe sunspots. If possible, begin the investigation on a sunny day by observing sunspots with a telescope or binoculars. This can be done by pointing the telescope or binocular in the general direction of the sun and then moving it until a circular shadow forms on the ground. TAKE CARE THAT AT NO TIME DOES ANYONE LOOK THROUGH THE EYEPIECE. EVEN A MOMENTARY IMAGE CAN CAUSE DAMAGE. A piece of paper placed perpendicular to the plane of the eyepiece should provide a good image. Focus the telescope or binocular until a clear image is produced.

2. Discuss briefly with students the nature of sunspots. This may be deferred until after the students have graphed the data.

3. Have students graph the data from 1900 to 1969 and interpret it. (see student direction sheet). A variation would be to assign the plotting of the complete record of sunspots (1750-1969) to a small group of students.

TYPICAL RESULTS:

A general pattern should emerge yielding an average sunspot cycle of about 11 years.

MODIFICATIONS:

If the existence of sunspots is demonstrated as suggested in the approach, it may be possible for students to collect their own data over a period of time. This data can then be explored to determine if there is a shorter range cycle (i.e. weekly or monthly).

REFERENCES:

Investigating the Earth, pp. 20-21, Teacher's Guide, pp. 45-47.
Sky and Telescope - Monthly listing of sunspots.
Preliminary Report and Forecast of Solar-Geophysical Activity, prepared by Space Disturbance Forecast Center, ESSA, U.S. Department of Commerce, Boulder, Colorado 80302

II-A-1a: SUNSPOT ANALYSIS

QUESTION:

How can changes be described?

INTRODUCTION:

Sometimes changes in nature appear to follow a pattern. This may not always be obvious at first but, if studied over a period of time it may become apparent. One of the best ways to study the behavior of something over a long period of time is to make many individual measurements and graph your results. This gives you a picture-like way of seeing relationships which might otherwise remain hidden.

In this investigation you will graph data which was collected over a period of many years by many observers.

OBJECTIVES:

When you have finished this investigation you should be able to:

1. choose an appropriate scale and prepare a graph, given a set of data.
2. identify, from a graph of sunspot data, the times of maximum and minimum activity.
3. Describe the characteristics of the curve from a graph of sunspot data.

METHOD:

Plot the data from 1900-1969 that appear on the accompanying table. Use the graph to answer the questions that appear below.

QUESTIONS:

(A-1.41) 1. Describe the pattern shown by the graph?

(A-1.51) 2. How many sunspots will there be in the year that you graduate from high school?

(A-1.51) 3. When will the next sunspot maximum be reached?

Supplementary Sheet #1

ANNUAL SUNSPOT NUMBERS

Year	No. Sunspots	Year	No. Sunspots	Year	No. Sunspots
1750	83	1794	41	1838	103
1751	47	1795	21	1839	85
1752	47	1796	16	1840	63
1753	30	1797	6	1841	36
1754	12	1798	4	1842	24
1755	9	1799	6	1843	10
1756	10	1800	14	1844	15
1757	32	1801	34	1845	40
1758	47	1802	45	1846	61
1759	54	1803	43	1847	98
1760	62	1804	47	1848	124
1761	85	1805	42	1849	95
1762	61	1806	28	1850	66
1763	45	1807	10	1851	64
1764	36	1808	8	1852	54
1765	20	1809	2	1853	39
1766	11	1810	0	1854	20
1767	37	1811	1	1855	6
1768	69	1812	5	1856	4
1769	106	1813	12	1857	22
1770	100	1814	13	1858	54
1771	81	1815	35	1859	93
1772	66	1816	45	1860	95
1773	34	1817	41	1861	77
1774	30	1818	30	1862	59
1775	7	1819	23	1863	44
1776	19	1820	15	1864	47
1777	92	1821	6	1865	30
1778	154	1822	4	1866	16
1779	125	1823	1	1867	7
1780	84	1824	8	1868	37
1781	68	1825	16	1869	73
1782	38	1826	36	1870	139
1783	22	1827	49	1871	111
1784	10	1828	62	1872	101
1785	24	1829	67	1873	66
1786	82	1830	71	1874	44
1787	132	1831	47	1875	17
1788	130	1832	27	1876	11
1789	118	1833	8	1877	12
1790	89	1834	13	1878	3
1791	66	1835	56	1879	6
1792	60	1836	121	1880	32
1793	46	1837	138	1881	54

Supplementary Sheet #2

ANNUAL SUNSPOT NUMBERS, Continued

Year	No. Sunspots	Year	No. Sunspots	Year	No.Sunspots
1882	59	1910	18	1938	109
1883	63	1911	5	1939	88
1884	63	1912	3	1940	67
1885	52	1913	1	1941	47
1886	25	1914	9	1942	30
1887	13	1915	47	1943	16
1888	6	1916	57	1944	11
1889	6	1917	103	1945	33
1890	7	1918	80	1946	92
1891	35	1919	63	1947	151
1892	72	1920	37	1948	136
1893	84	1921	26	1949	134
1894	78	1922	14	1950	83
1895	64	1923	5	1951	69
1896	41	1924	16	1952	31
1897	26	1925	44	1953	13
1898	26	1926	63	1954	4
1899	12	1927	69	1955	38
1900	9	1928	77	1956	141
1901	2	1929	65	1957	189
1902	5	1930	35	1958	184
1903	24	1931	21	1959	158
1904	42	1932	11	1960	112
1905	63	1933	5	1961	53
1906	53	1934	8	1962	37
1907	62	1935	36	1963	27
1908	48	1936	79	1964	10
1909	43	1937	114		

Adapted from:

Investigating the Earth, Teacher's Guide.

Challenging (0.5)

II-C-1a: ROADSIDE POLLUTANTS

QUESTION:

How does man modify the environment?

MATERIALS:

Student sheet.

SUGGESTED APPROACH:

1. Conduct a discussion concerning how an investigation might be conducted, and how one was conducted, to determine the amount of pollutants contained in roadside vegetation and soil.
2. Assign the investigation as homework.
3. Following the completion of the assignment, conduct a discussion of:
   a) relationship between metal concentration and distance from highway.
   b) relationship between metal concentration and depth in soil.
   c) possible sources of the metals.
   d) effect of an increase in numbers of automobiles in U.S. — alternatives such as mass transport systems.
   e) land use for transportation vs. agriculture, which should have priority?

TYPICAL RESULTS:

1. Observations might include:
   a) increasing concentrations of metals with increasing distance from road and decreasing concentrations of metals with increasing depth in the soil.
2. Inferences might include:
   a) source of pollutants
      1) lead - from leaded gasolines used by autos
      2) nickel - from some gasolines and atmospheric abrasion of auto parts containing nickel.
      3) zinc and cadmium - from oils and some tires
      4) zinc - from galvanized auto parts, tanks and conduits

MODIFICATIONS:

1. In many areas of New York State new 4-lane expressways are being constructed or planned. Find out what is being planned in your area. Perhaps you could invite opposing guest speakers such as a conservationist opposing construction and a highway planner encouraging construction.

BACKGROUND INFORMATION:

1. Some pertinent information about lead:

   a) Most gasolines contain lead additives — unleaded gas is available.

   b) Lead, typical of that used in gasoline, has been detected at distances of over 100 miles from the nearest metropolitan area.

   c) In 1964 — 100,000 tons of lead, representing 10% of the U.S. consumption during that year was discharged into the atmosphere as a result of gasoline combustion.

   d) Concentrations of 0.5 parts per million in the human bloodstream will cause lead poisoning symptoms. Death may result at higher levels.

2. In the year 1900, the auto industry was just beginning; in 1934, there were 24,933,403 autos registered in the U. S.; in 1954, there were 58,622,547; in 1964, there were 86,297,133 and in 1970, over 100,000,000.

REFERENCES:

Contamination of Roadside Soil and Vegetation with Cadmium, Nickel, Lead, and Zinc by Lagerwerff and Specht; U.S. Soils Laboratory, Beltsville, Maryland, 20705; pp. 583-586; Environmental Science and Technology, Vol. 4, Number 7, July 1970.

Wheels, Wings and Water — a report on New York State's mobility — 1969, State of New York Legislative Document (1969) Number 86; Senator Edward J. Speno, Chairman of Committee on Mass Transport.

II-C-1a: ROADSIDE POLLUTANTS

QUESTION:

How does man modify the environment?

INTRODUCTION:

Scientists working in Maryland collected samples of vegetation and soil alongside a busy highway. They analyzed the samples to determine the quantity of four metallic pollutants (cadmium, nickel, lead, and zinc). The results have been organized in the data table below.

Pollutants Found in
Roadside Grass and Soil

(Expressed in parts per million mass)

Metal	Meters from Road	Grass	0-5 cm. depth	5-10 cm. depth	10-15 cm. depth
Cadmium	8	0.95	1.45	0.76	0.54
	16	0.73	0.40	0.38	0.28
	32	0.50	0.22	0.20	0.20
Nickel	8	5.0	4.7	1.0	0.81
	16	3.8	2.4	0.90	0.60
	32	2.8	2.2	0.62	0.59
Lead	8	68.2	522	460	416
	16	47.5	378	260	104
	32	26.3	164	108	69
Zinc	8	32.0	175	94	72
	16	28.5	66	48	42
	32	27.3	54	46	42

Sampling site is west of U.S. 1, Beltsville, Maryland
Average traffic conditions - 20,000 cars per 24-hr. day.

OBJECTIVES:

When you have finished this investigation you should be able to:

1. Analyze numerical data and identify relationships represented by the data.

METHOD:

1. Examine the data table and draw some inferences concerning:

   a) The pattern of metal concentrations with increasing distance from the highway.

   b) The pattern of metal concentrations with increasing depth in soil.

   c) The relative concentrations of the four metals.

QUESTIONS:

1. What patterns in the data are you able to observe?

(C-1.12) (C-1.11) 2. What effect has man had on this natural environment?

(C-1.21) 3. Why are these four metals considered to be pollutants?

(C-1.23) 4. What do you infer to be the primary sources of these pollutants? What are some other possible sources?

Easy (0.5)

II-C-1b: AIR POLLUTION - HUMAN MORTALITY

QUESTION:

How does man modify the environment?

MATERIALS:

Student sheet.

SUGGESTED APPROACH:

1. Conduct a discussion concerning how an investigation measuring the effect of air pollution on human death rate might be conducted.
2. Assign the investigation as homework.
3. Following the completion of the assignment, conduct a discussion of:
   a) particulate matter composition.
   b) type of relationship between particulate matter and death rate.
   c) general effects of air pollution on man.

PRECAUTIONS:

1. The base for the "unit increase in particulate matter" was not identified, however the fact that the highest increase experienced was 5 units provides a general reference scale.

MODIFICATIONS:

1. Ask a local doctor to discuss air pollution health problems with the students.
2. Ask your government representatives to discuss present and predicted legislation controlling air pollution.

BACKGROUND INFORMATION:

1. Particulate matter contains, among other things, known toxic substances such as lead, the carcinogenic hydrocarbon, benzopyrene, and asbestos.
2. A recent study during which autopsies were performed on the lungs of 300 ex-residents of heavily polluted St. Louis and on an equal number from relatively unpolluted Winnipeg, Canada proved:
   a) among cigarette smokers 4 times as many individuals from St. Louis had severe emphysema as those from Winnipeg.
   b) among nonsmokers 3 times as many individuals from St. Louis had mild to moderate emphysema as those from Winnipeg.
3. Air pollution also:
   a) rots and soils clothes, discolors house point, rusts metals, mars monuments, decreases visibility, can ground planes and make driving dangerous.

b) stunts the growth of vegetables, shrubs, flowers; damages fruit trees, sickens cattle, and ruins crops.

REFERENCES:

Short-term Effects of Air Pollution on Mortality in New York City by Thomas Hodgson, Jr., Cornell Medical College, New York, N. Y.; pp. 589-597; Environmental Science and Technology, Vol. 4, Number 7, July 1970.

II-C-1b: AIR POLLUTION - HUMAN MORTALITY

QUESTION:

How does man modify the environment?

INTRODUCTION:

A short time ago the Surgeon General of the U.S. in his testimony before Congress admitted that "substantive evidence of the direct effect of common day-to-day air pollution on health is lacking." Since that time investigations have been conducted that better identify the relationship between air pollution and health problems. The data table below was adapted from such an investigation.

Expected Increase in Deaths Resulting From a Unit Increase in Particulate Matter in the Atmosphere.

*Increases may be as large as 5 units per day (on rare occasions).

Category of Deaths	Average Number of Daily Deaths for Study Period	% Increase in deaths from unit increase in particles
Pneumonia	9.40	20
Bronchitis	0.81	21
Arteriosclerotic Heart Disease	85.80	8
Hypertensive Heart Disease	8.33	19
Other Diseases of the Heart etc.	18.03	9
Respiratory and Heart Diseases	150.55	9

Based on a 2-1/2 year study in New York City. (November 1962-May 1965) (Data table adapted from Environmental Science and Technology, July 1970)

OBJECTIVES:

When you have finished this investigation you should be able to:

1. analyze numerical data and identify relationships represented by the data.

METHOD:

1. Examine the data table and draw some inferences concerning:

   a) the increases in deaths due to increases in particulate matter pollution.

   b) the types of diseases that are most drastically affected by an increase in particulate matter.

QUESTIONS:

1. What patterns in the data are you able to observe?

(C-1.12) (C-1.23) 2. What do you think the sources of this particulate matter are?

(C-1.21) 3. Why is this atmospheric environment referred to as being polluted?

SUPPLEMENTARY MATERIALS FOR TOPIC II

The nature of Topic II requires a great deal of information that is available from a wide variety of sources.

Materials are included under the following headings:

1. Government agencies which publish literature dealing with environmental pollution.
2. List of Free Earth Science Teaching Materials available from the New York State Museum and Science Service.
3. A Bibliography of topics including the following:

Laboratory Manuals and Supply Catalogs on Pollution
Films on Pollution
Filmstrips on Pollution
Air Pollution
General Environmental Pollution
Water Pollution
Pesticide Pollution
Radiation Pollution
Population Problems
Solid Wastes Pollution
Magazines, Journals, and Periodicals on Pollution
Ragweed Pollen Survey

Government Agencies which publish literature dealing with environmental pollution:

1. Federal Government

a. Federal Water Pollution Control Administration
Department of Interior
4676 Columbia Parkway
Cincinnati, Ohio 45226

b. National Air Pollution Control Administration
United States Public Health Service
Department of Health, Education and Welfare
801 North Randolph Street
Arlington, Virginia 22203

c. Environmental Control Administration
United States Public Health Service
Department of Health, Education and Welfare
P.O. Box 30200
Cincinnati, Ohio 45230

d. United States Atomic Energy Commission
Division of Technical Information
Washington, D. C. 20545

e. Bureau of Mines
Department of the Interior
4800 Forbes Avenue
Pittsburgh, Pennsylvania 15213

2. New York State Government

a. Division of Air Resources
New York State Department of Health
84 Holland Avenue
Albany, New York 12208

b. Division of Pure Waters
New York State Department of Health
84 Holland Avenue
Albany, New York 12208

c. Division of General Engineering and Radiological Health
New York State Department of Health
84 Holland Avenue
Albany, New York 12208

d. New York State Conservation Department
State Office Campus
Albany, New York 12226

e. New York State Department of Agriculture and Markets
State Office Campus
Albany, New York 12226

LIST OF FREE EARTH SCIENCE TEACHING MATERIALS AVAILABLE FROM THE NEW YORK STATE MUSEUM AND SCIENCE SERVICE

Free Loan Sets of Minerals, Rocks, and Fossils

1. Loan set of rocks and minerals of New York State; set contains 30 mineral and rock samples plus item 5 below.
2. Loan set of representative fossils of New York State; set contains 20 fossils, plus item 18 listed below.

Free Subscriptions

1. Geogram, a triannual publication of the Geological Survey.

2. Museum Education, a monthly publication describing educational activities and services of the New York State Museum.

Free Publications and Reprints

1. Geological Map of New York State. This is an 8 1/2" x 11" geological map on which is superimposed the grid of 15' topographic guadrangles of the State. It is designed for hand-coloring by students.

2. Mineral resources map of New York State, 8 1/2" x 11".

3. Price list of available geological maps issued by the New York State Museum and Science Service.

4. Price list of publications in geology and paleontology published by the New York State Museum and Science Service.

5. "Rocks and Minerals of New York State," a 20-page illustrated booklet giving definitions and properties of minerals and rocks, criteria for identification, and descriptions of individual minerals and rocks. This leaflet (#10) contains the two 8 1/2" x 11" maps referred to above. One copy free to teachers; cost for others - 25¢.

6. "Some Mineral Collecting Localities of New York State," a pamphlet describing 36 mineral collecting localities within the State; pamphlet also contains the two 8 1/2" x 11" maps referred to above.

7. "The Field Identification of Rocks," a 22-page booklet illustrated with photographs which aid teachers and students in the identification of rocks. One copy free to teachers; cost for others - 25¢.

8. "An Open Letter to Fossil Collectors," lists 14 books useful in the identification and study of fossils as well as other brief notes of interest to fossil collectors.

9. "Mirror to the Past," a color-illustrated leaflet describing the major phyla and classes of fossil invertebrates found in New York State.

10. "300 Million Years Ago," a color-illustrated leaflet describing fossil fishes of New York State.

11. "Prehistoric Mammals of New York," an illustrated leaflet discussing the fossil mammals of New York State

12. "Mammoths and Mastodons, Ice-Age Elephants of New York State," an illustrated 31-page leaflet (#13). One copy free to teachers; cost for others - 50¢.

13. "An Ancient Beachhead," a color-illustrated leaflet describing the fossil plants of New York State.

14. "The Oldest Forest and the Naples Tree," a 24-page illustrated leaflet (#14). One copy free to teachers; cost for others - 25¢.

15. "Geological History of the Adirondack Mountains," a color-illustrated leaflet describing the geological evolution of the Adirondacks over the past billion years.

16. "Field Guide to the Central Portion of the Southern Adirondacks," a 34-page geological guide to the area (#12). One copy free to teachers; cost for others - 75¢.

17. Educational Leaflet #18, an 85-page geological guide to the Mohawk Valley and the area from the Capital District northward into the southern Adirondacks in the Lake George area. One copy free to teachers; cost for others - 50¢.

18. "An Introduction to Invertebrate Fossils of New York," a 17-page illustrated leaflet (#19). One copy free to teachers; cost for others - 25¢.

19. "Geology of New York - a short account," a 49-page illustrated leaflet (#20), with a large color bedrock map. One copy free to teachers; cost for others - $1.00.

SEND REQUESTS AND CHECKS TO:
Museum Office
N.Y.S. Museum and Science Service
Albany, New York 12224

MAKE CHECKS PAYABLE TO:
N.Y.S. Education Department

LABORATORY MANUALS AND SUPPLY CATALOGS ON POLLUTION

A Teachers' Packet for Conservation Information and Education, New York State Conservation Dept. Education, Albany, N. Y.

ABATES Packet, New York State Health Department, Division of Pure Waters, 84 Holland Avenue, Albany, N. Y.

Air Pollution Experiments, High School Edition, Cooperative Extension Service, College of Agriculture and Environmental Science, Rutgers University, New Brunswick, N.J.

Air Pollution Experiments for Junior and Senior High School Science Classes by Donald C. Hunter and Henry C. Wohlers, Air Pollution Control Association, 4400 Fifth Avenue, Pittsburgh, Penna.

Conserving our Waters and Clearing the Air, Study Unit for Science and Social Studies Classes, Teachers Guide, Student Manual, Reference Materials, American Petroleum Institute, 1271 Avenue of the Americas, New York, N.Y.

Environmental Pollution Educational Module, Ward's Natural Science Establishment, P. O. Box 1712, Rochester, N.Y.

Microbiological Analysis of Water, Millipore Corporation, Bedford, Mass.

Science Demonstration Equipment, LaMotte Chemical Products Company, Educational Products Division, Chestertown, Md.

Scientific Experiments in Environmental Pollution by Elbert C. Weaver, Holt, Rinehart and Winston, Inc., New York, N.Y.

Simplified Laboratory Procedures for Wastewater Examination, Water Pollution Control Federation, 3900 Wisconsin Avenue, Washington, D. C., $3.00.

Simplified Procedures for Water Examination, American Water Works Association, 2 Park Avenue, New York, N. Y., $6.00.

Teaching About Air Pollution, Albert B. Carr, reprint from School Science and Mathematics. P. O. Box 246, Bloomington, Ind.

Water and Wastewater Analysis Procedures, Hach Chemical Company, P. O. Box 907, Ames, Iowa.

FILMS ON POLLUTION*

Tom Lehrer Sings "Pollution"
With Each Breath
The First Mile Up
Air Pollution in the News
Ill-Winds on a Sunny Day
Moto Gaz
Take a Deep Breath
Air Pollution, Everyone's Problem
Our Air
The Runaround

*Available from the New York State Department of Health Film Library, 84 Holland Ave., Albany, N.Y.

FILMSTRIPS ON POLLUTION

Crisis of the Environment, New York Times, Book and Educational Division, 229 West 43rd Street, New York, N. Y., $97.50.

Environmental Pollution - Our World in Crises, Ward's Natural Science Establishment, P. O. Box 1712, Rochester, N. Y., $40.00.

Water for Tomorrow, Air for Tomorrow, Land for Tomorrow, KDI Instructional Systems, Inc., 1810 Mackenzie Drive, Columbus, Ohio, $35.00 each.

AIR POLLUTION

A Primer on Air Pollution, Mobil Oil Corporation, 150 East 42nd Street, New York, N.Y.

Air and Water Pollution, (Problems in American Society Series), edited by Gerald Leinwand, 1969, Washington Square Press.

Air Conservation, 1965, American Association for the Advancement of Science, Washington, D. C.

Air Pollution, 1969, Life Educational Reprint 69, Life Educational Reprint Program, New York, N.Y.

Air Pollution, 1960, Power Magazine, McGraw-Hill Publishing Co., New York, N.Y.

Air Pollution, 1966, University of the State of New York, State Education Department, Albany, N.Y.

Air Pollution - A National Problem, Public Health Service Publication No. 975, National Center for Air Pollution Control.

Air Pollution - A National Sample, Public Health Service Publication No. 1562, National Center for Pollution Control.

Air Pollution and Community Health, Clarence Mills, 1954, The Christopher Publishing House, Boston, Mass.

Air Pollution and Respiratory Disease, Public Health Service Publication, No. 1257, National Center for Air Pollution Control.

Air Pollution: Where Are We Going?, Dr. John T. Middletown, National Air Pollution Control Administration, Department of Health, Education and Welfare, Washington, D. C.

Air Pollution Primer, 1969, National Tuberculosis and Respiratory Disease Association.

Clean Air Act as Amended (Highlights), National Air Pollution Control Administration, Washington, D.C.

Clean Air for Your Community, 1967, Public Health Service Publication No. 1544.

Clear the Air, Alfred Lewis, 1965, McGraw-Hill Book Company.

Clearing the Air, United States Department of the Interior, Bureau of Mines, Pittsburgh, Penna.

Clearing the Air - A Layman's Guide to Atmospheric Purity, American Petroleum Institute, 1217 Avenue of the Americas, New York, N.Y.

Guide to the Appraisal and Control of Air Pollution, 1969, American Public Health Association, 1740 Broadway, New York, N. Y.

Health Officials' Guide to Air Pollution Control, 1962, American Public Health Association, New York, N.Y.

Killer Smog, William Wise, 1968, Rand McNally Publishing Company.

No Laughing Matter - The Cartoonist Focuses on Air Pollution, Public Health Service Publication No. 1561, National Center for Air Pollution Control.

Physicians' Guide to Air Pollution, 1968, American Medical Association, 535 North Dearborn Street, Chicago, Ill.

Preserving Our Air Resources, New York State Health Department, Division of Air Resources, 84 Holland Avenue, Albany, N.Y.

Proceedings: National Conference on Air Pollution, 1962, Public Health Service Publication No. 1022.

Proceedings: The Third National Conference on Air Pollution, 1966, Public Health Service Publication No. 1469.

Some Health Aspects of Air Pollution, City of New York, Environmental Protection Administration, Department of Air Resources, 51 Astor Place, New York, N . Y.

Sun/Air and Wheels, 1967, General Motors Corporation, Detroit, Mich.

Take Three Giant Steps to Clean Air, 1967, Public Health Service Publication No. 1551.

The Battle for Clean Air, Edward Edelson, Public Affairs Pamphlet No. 403, Public Affairs Pamphlets, 381 Park Avenue South, New York, N.Y.

The Breath of Life, Donald Carr, 1965, Norton Publishing Company.

The Effects of Air Pollution, Public Health Service Publication - No. 1556, National Center for Air Pollution Control.

The Federal Air Pollution Program, Public Health Service Publication No. 1560, National Center for Air Pollution Control. Public Health Service, Washington, D. C.

The Sources of Air Pollution and Their Control, Public Health Service Publication No. 1548, National Center for Air Pollution Control.

The Unclean Sky, 1966, Louis J. Battan, Anchor Books, Doubleday and Company, Garden City, N. Y.

Today and Tomorrow in Air Pollution, Public Health Service Publication No. 1555, National Center for Air Pollution Control.

Trouble Air, Public Health Service Publication No. 977, National Center for Air Pollution Control.

What's in the Air?, Hazel Holly, Public Affairs Pamphlet No. 275.

With Every Breath You Take, Howard Lewis, 1965, Crown Publishing Company.

GENERAL ENVIRONMENTAL POLLUTION

America the Raped, Gene Marine, 1969, Simon and Schuster, New York, N. Y.

An Environment Fit for People, Raymond Dasmann, Public Affairs Pamphlet No. 421, Public Affairs Pamphlets, 381 Park Avenue South, New York, N. Y. 10016.

Biological Conservation, David Ehrenfeld, 1970, Holt, Rinehart and Winston, Inc., New York, N.Y.

Cleaning Our Environment: The Chemical Basis for Action, 1969, American Chemical Society, 1155 16th Street, N.W., Washington, D. C.

Controlling Pollution - The Economics of a Cleaner America, edited by Marshall I Goldman, 1967, Prentice-Hall, Inc., Englewood Cliffs, N.J.

Crisis in Eden - A religious Study of Man and Environment, Frederick Elden, 1970, Abingdon Press, Nashville, Tenn.

Crisis in Our Cities, Lewis Herber, 1965, Prentice-Hall, Inc.

Ecotactics, The Sierra Club Handbook for Environmental Activists, edited by John G. Mitchell and Constance L. Stalling, 1970, Ballatine Books, 101 Fifth Avenue, New York, N.Y.

Environmental Problems and Action Programs in The State of New York, 1967, New York State Natural Beauty Commission, Albany, N. Y.

Environmental Quality, The Recommendations of the President's Council on Recreation and Natural Beauty, 1968, New York State Natural Beauty Commission, 155 Washington Avenue, Albany, N.Y.

Environmental Quality in a Growing Economy, Henry Jarrett, 1966, John Hopkins University Press, Baltimore, Md.

For The Benefit of Man, Bureau of Mines, Washington, D. C., 1965.

God's Own Junkyard: The Planned Deterioration of America's Landscape, Peter Blake, 1964, Holt, Rinehart and Winston, New York, N.Y.

Moment in the Sun, A Report on the Deteriorating Quality of the American Environment, Robert Rienow and Leona Train Rienow, 1967, Ballatine Books.

Not So Rich As You Think, George R. Stewart, 1968, Houghton Mifflin Company, Boston, Mass.

Our Polluted World, John Perry, 1967, Franklin Watts, Inc. (Grolier Enterprises), Lexington Avenue, New York, N. Y.

Our Precarious Habitat, Dr. Melvin Benarde, 1970, W. W. Norton and Company, 55 Fifth Avenue, New York, N.Y.

Quality of the Environment - An Economic Approach to Some Problems in Using Land, Water and Air, Orris Herfindahl and Allen Kreese, John Hopkins Press, Baltimore, Md 21218.

Restoring the Quality of Our Environment, President's Science Advisory Committee, 1965, Superintendent of Documents, Washington, D.C.

Science and Survival, Dr. Barry Commoner, 1966, Viking Press.

Strategy for a Livable Environment, Task Force on Environmental Health and Related Problems, 1967, Superintendent of Documents, Washington, D.C.

Terracide: America's Destruction of Her Living Environment, Ron Linton, 1970, Little, Brown and Company, Boston, Mass.

The Dirty Animal, Henry Still, 1967, Hawthorne Books, Inc., 70 Fifth Avenue, New York, N. Y.

The Dynamic Spectrum: Man, Health and Environment, 1966, National Sanitation Foundation, Ann Arbor, Mich.

The Environment, A National Mission for the Seventies, the Editors of Fortune, 1970, Harper and Row, 49 East 33rd Street, New York, N.Y.

The Environmental Crisis - Man's Struggle to Live with Himself, edited by Harold Helfrich, Jr., 1970, Yale University Press, New Haven, Conn.

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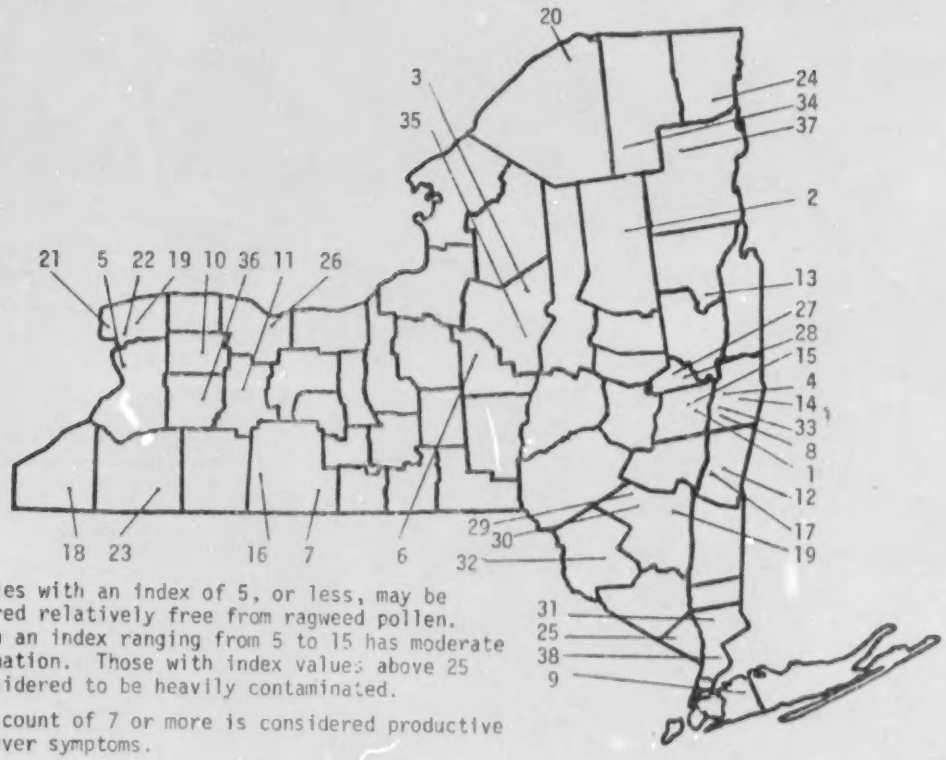
NEW YORK STATE DEPARTMENT OF HEALTH

RAGWEED POLLEN SURVEY



Localities with an index of 5, or less, may be considered relatively free from ragweed pollen. One with an index ranging from 5 to 15 has moderate contamination. Those with index values above 25 are considered to be heavily contaminated.

A daily count of 7 or more is considered productive of hayfever symptoms.

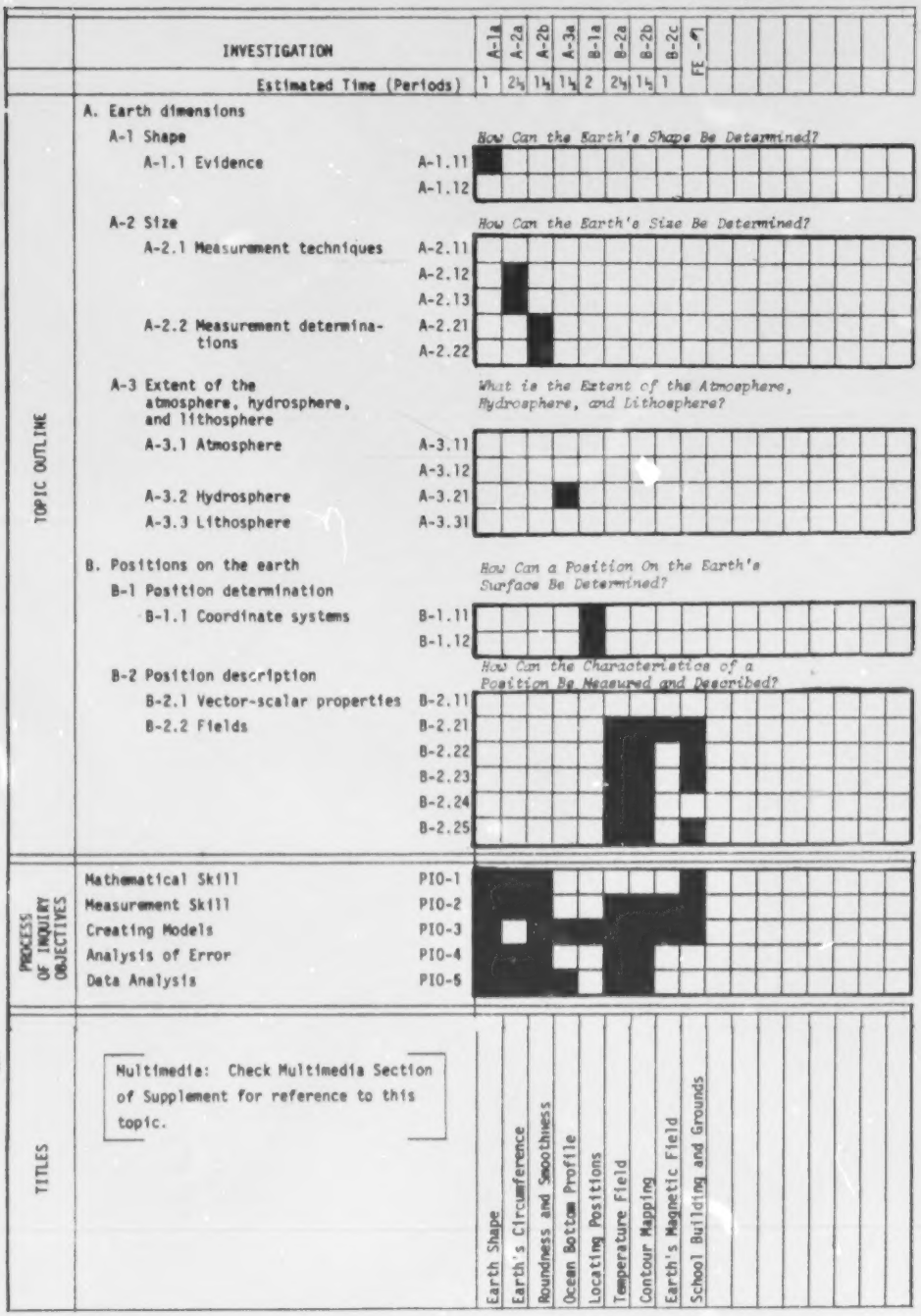
Map Location	Municipality	Index 67	Index 68	Index 69	Hayfever Days 67	Hayfever Days 68	Hayfever Days 69
1	Albany	24	26	26	18	18	18
2	Blue Mnt Lake		2		1		
3	Boonville	15	14	19	11	0	13
4	Brunswick	55	9	13	41	6	9
5	Buffalo	21	33	69	14	18	35
6	Canastota		31			22	
7	Corning	35	21	24	25	14	16
8	E. Greenbush	65	16	15	45	11	10
9	Garden City	22	13	34	14	9	25
10	Batavia	14	29	26	11	21	19
11	Geneseo	31	29		22	20	
12	Ghent	23	24	38	16	17	23
13	Glens Falls	15	18	15	11	12	25
14	Grafton	18	2	19	12	1	6
15	Guilderland	15	21	21	11	14	13
16	Hornell	10	15	19	7	11	14
17	Hudson	10	11	17	7	6	12
18	Jamestown		33	43	1	25	34
19	Lockport	28	18	25	21	13	17

Map Location	Municipality	Index 67	Index 68	Index 69	Hayfever Days 67	Hayfever Days 68	Hayfever Days 69
20	Massena	44	35	42	25	22	26
21	Niagara Falls	24	29	34	17	18	23
22	North Tonawanda	34	34	38	25	22	23
23	Olean	18	29	23	12	20	16
24	Plattsburg	6	13	6	4	9	4
25	Ramapo	5	43		3	25	
26	Rochester	34	31		26	20	
27	Rotterdam	18	10	15	13	7	9
28	Schenectady	11	70	23	7	25	15
29	Shandaken		2	3		1	1
30	Shandaken		6	10		4	7
21	Shrub Oak		14	13		10	9
32	South Fallsburg	4	11	8	2	7	5
33	Troy	77	2	20	54	1	14
34	Tupper Lake		8	22		5	16
35	Utica	23	17	16	18	12	12
36	Warsaw	28	46	34	21	30	22
37	Whiteface Mtn Wilmington	0	5		0	3	
38	White Plains	3	16	22	1	11	16
39	Woodstock		7	4		4	2

topic III

What Is Our Model of the Earth?

Time Emphasis: 10 days



III-A-1a: EARTH'S SHAPE

QUESTION:

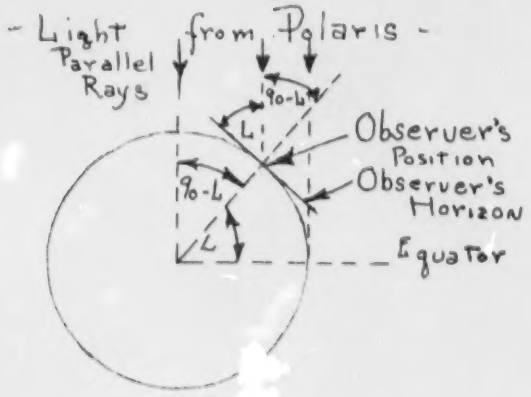
How can the earth's shape be determined?

MATERIALS:

Astrolabe.

SUGGESTED APPROACH:

1. Have students make a sighting of Polaris' altitude at home, using either an astrolabe or the handspan method.
2. Using a globe, develop the understanding that the altitude of Polaris is equal to the latitude of the position from which Polaris was sighted. (See diagram.) Ask what the local latitude must be.



Given the distance in kilometers from the equator to the north pole, have students calculate the distance that would be covered for every 10° of latitude traveled, assuming that the earth is a perfect sphere. Have students compare their calculated values with the actual measured values.

Km./10° change of latitude	
0-10° - 1105.7	40-50° - 1108.7
10-20° - 1106.0	50-60° - 1110.2
20-30° - 1106.6	60-70° - 1112.0
30-40° - 1107.5	70-80° - 1114.1
	80-90° - 1116.5

MODIFICATIONS:

1. If work has previously been done on pendulum measurements of gravity, have students compare the results of this exercise with the data in the following table:

Length of a Pendulum Which Swings Once per Second

Latitude (°)	Pendulum Length (inches)
0	39.01
10	39.02
20	39.04
30	39.07
40	39.10
50	39.14
60	39.17
70	39.20
80	39.21
90	39.22

REFERENCES:

Investigating the Earth, pp. 70-73, Teacher's Guide, pp. 106-108, 117
Exploring Earth Science, pp. 156-157
Focus on Earth Science, pp. 24-28

III-A-1a: EARTH'S SHAPE - POLARIS DETERMINATION

QUESTION:

How can the earth's shape be determined?

INTRODUCTION:

Sketch what you think is an accurate representation of the earth's shape. What shape is it? Keep your sketch and compare it with the model which will be developed during this investigation. How could you obtain data that could be used to make an accurate scale model of the shape of the earth?

OBJECTIVES:

When you finish this investigation you should be able to:

1. state the latitude of a position, given the altitude of Polaris at that position.
2. explain why the observed altitude of Polaris is numerically equivalent to the latitude of the observer.
3. choose from among several given models the one that best represents the true shape of the earth, and defend your choice.

METHOD:

1. Using an astrolabe or the hand span method, make a sighting of the altitude of Polaris. The altitude of Polaris is always equal to the latitude of the observer. Make a diagram that will show why this is true.
2. Assume that you could travel from the equator to the pole and that as you traveled you took sightings of Polaris to determine your latitude. If the distance from the equator to the pole is 10,000 kilometers, and assuming that the earth is a perfect sphere, calculate how many kilometers would be covered for every 10° of latitude you traveled.
3. Compare the distance obtained above with the actual measured distances provided by your teacher.
4. Develop a model of the earth's shape that would take into account the data from #3. How close to a perfect sphere is the earth?

QUESTIONS:

(A-1.11) 1. What is the relationship between the altitude of Polaris and an observer's latitude? Explain by means of a diagram.

(A-2.21) 2. How would the earth's circumference measured along the equator compare its circumference measured through the poles?

(A-1.11) 3. What is the earth's shape? List evidence to support your answer.

(A-2.22) 4. If you had an exact scale model of the earth the size of a basketball, how near a perfect sphere would the model be?

Challenging (2.5)

III-A-2a: EARTH'S CIRCUMFERENCE

QUESTION:

How can the earth's size be determined?

MATERIALS:

Globe or sphere, clay, two toothpicks, protractor, flexible centimeter ruler, string and weight, ring stand.

SUGGESTED APPROACH:

1. Have the students fasten toothpicks about 5 cm. apart, on a line of longitude, as in the diagram on the student's sheet; measure distance "S" and the shadow angle "L". Repeat the procedure at least twice using different areas on the globe.

2. Use the chalkboard or overhead projector to develop the equation; $\frac{S}{C} = \frac{L}{360°}$,

   where S = measured distance; C = unknown circumference; L = measured angle. After the students understand the equation, have them calculate the circumference, using the average of the data obtained.

3. The students should measure the circumference of the model. They should compare the calculated and measured results, and calculate the percent error.

4. Have the students calculate the diameter and the volume, using their experimental data.

5. Discuss with the students what additional data they would need to calculate the earth's circumference when given their shadow angle "L". If the students can use the analemma, they can easily find at what latitude the sun will be at the zenith on this date. The distance can be calculated by assuming 1° of latitude = 70 miles.

6. When the sun is at its highest altitude, have the students measure the angle the sun makes with the vertical. With this angle and the information given on the supplementary sheet have them compute the earth's circumference.

PRECAUTIONS:

1. Percent error should not be greater than 10% (20% indoors with bulb).

2. Be sure the students understand why the formula used is valid. To do this, they must realize that the sun's rays are parallel and that alternate interior angles are always equal.

3. The students will need some help in using the protractor properly to measure the shadow angle.

4. Sticks mounted on the globe must be perpendicular to the surface of the globe at that point.

5. If at all possible, do this investigation outside. An artificial light source, such as a light bulb results in a loss of accuracy due to diverging light rays.

MODIFICATIONS:

Obtain shadow angle data from a school directly north or south of you; use a map to determine the distance between the schools and use this data to calculate the earth's circumference.

REFERENCES:

Investigating the Earth, pp. 68-70, Teacher's Guide, pp. 102-106

III-A-2a: EARTH'S CIRCUMFERENCE

QUESTION:

How can the earth's size be determined?

INTRODUCTION:

Very often we want to know the size of objects that are either too large or too small to measure directly. In these cases we must use an indirect technique that usually involves a ratio between the size of something we can measure and the size of the object we are trying to find. In this investigation you will devise a method that could be used to find the size of the earth.

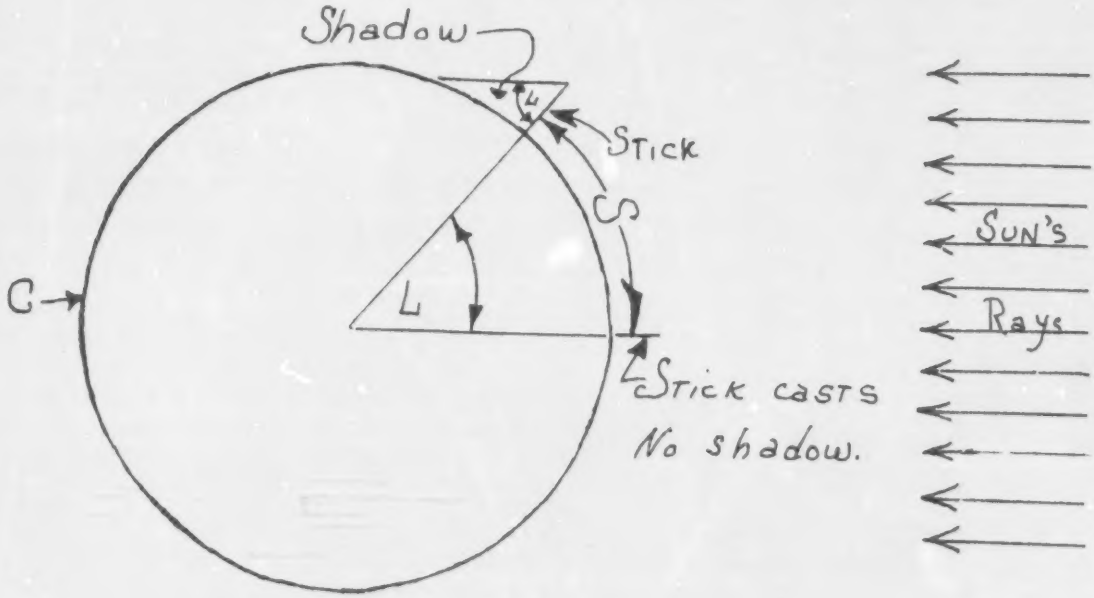
OBJECTIVES:

When you finish this investigation you should be able to:

1. measure distances on the globe to an accuracy of ± 0.2 cm.
2. observe and measure shadow angles to an accuracy of ± 5 degrees.
3. compute the globe's circumference using your data and the formula: $\frac{S}{C} = \frac{L}{360^\circ}$
4. given the circumference of a globe, calculate its diameter, volume, and surface area.
5. determine the percentage error using a calculated value and a standard value.
6. describe how the basic technique, used to determine the circumference of the model, could be used to determine the circumference of the earth.

METHOD:

1. Set up a globe (as in the diagram below) so that you can determine a shadow angle of a toothpick, which is supported by clay and points toward the center of the globe. This toothpick should be positioned at a measured distance from another similarly supported toothpick which casts no shadow.



2. Measure and record the shadow angle and distance between the two toothpicks. Repeat this for at least three separate positions of the toothpicks.

3. Use the equation: $\frac{S}{C} = \frac{L}{360°}$ to determine the circumference of the globe. (Where S = the distance measured between sticks, C = the unknown circumference of the globe, and L = the measured angle.) Repeat the calculations for each of the three sets of data and determine the average.

4. Measure the circumference of your globe directly.

5. Determine your percent of error.

6. Calculate the diameter of the globe using your experimental data.

7. Calculate the volume using your experimental data.

8. When the sun is highest in the sky (solar noon), measure the angle of a shadow from a vertical stick and record the angle. This procedure should be done with good sunlight conditions (i.e., sharp shadows).

9. Using your measured angle and the information given on the supplementary sheet, determine the earth's circumference.

QUESTIONS:

(A-2.12) 1. What is the basis for the technique you used to determine the circumference of the earth?

2. Could this technique be used to find the size of a flat earth? Explain.

3. What are some possible sources of error that could have influenced your determination of the earth's circumference?

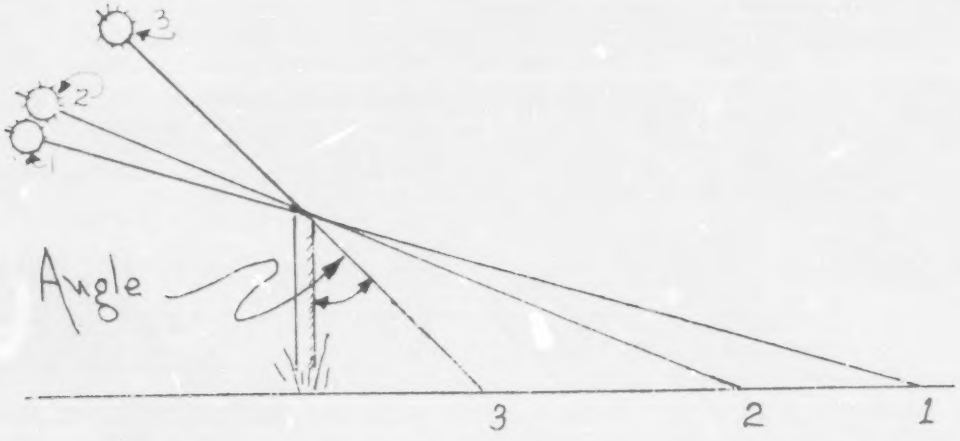
4. What other methods of determining the size of the earth might be used today?

(A-2.13) 5. Given the accepted polar circumference of 40,008 km., what is the diameter, volume, and surface area of the earth?

6. What is the percent of error in your computation of the earth's circumference from step 9? Use the circumference given in question 5.

SUPPLEMENTARY SHEET

EARTH'S CIRCUMFERENCE



1. Measure the angle of the sun at solar noon as illustrated in the diagram.

2. Use the measured angle and the information below to calculate the circumference of the earth.

Angle	*Distance(km.)	Angle	*Distance(km.)	Angle	*Distance(km.)
10	1110	26	2890	42	4670
11	1220	27	3000	43	4780
12	1330	28	3110	44	4890
13	1440	29	3220	45	5000
14	1560	30	3330	46	5110
15	1670	31	3450	47	5220
16	1780	32	3560	48	5330
17	1890	33	3670	49	5450
18	2000	34	3780	50	5560
19	2110	35	3890	51	5670
20	2220	36	4000	52	5780
21	2330	37	4110	53	5890
22	2440	38	4220	54	6000
23	2560	39	4330	55	6110
24	2670	40	4450	56	6220
25	2780	41	4560	57	6330
				58	6450
				59	6560

*Distance given represents the distance between location where your angular measurement was made and the location where there would be no shadow (sun at zenith)

Challenging (1.5)

III-A-2b: ROUNDNESS AND SMOOTHNESS

QUESTION:

How can the earth's shape be determined?

MATERIALS:

Globe (or some equivalent spherical object), ruler, caliper (for diameter) or flexible ruler (for circumference). Note: a strip of paper may be substituted for a flexible ruler.

SUGGESTED APPROACH:

1. Ask the students which they think is rounder and smoother, the earth or a globe. Have the students suggest ways to find out the answer to this question.

2. Have the students carry out their own procedures to determine the answer. The following is a description of one method:

   a. Roundness: Have the students determine the polar and equatorial diameter of the globe. Have the students find the decimal ratio of the two values. A perfect sphere would have a ratio of one, therefore, the closer to one, the more nearly spherical the object. Have the students determine a polar:equatorial diameter ratio for the earth and compare it to the ratio for the globe.

   b. Smoothness: Have the students measure (estimate if the actual value is less than 1 mm.) the height of any protrusion above the surface of the globe. Set up a ratio between this value and the average or approximate diameter of the globe. Develop the concept that the smaller the numerical result, the smoother the object. Have the students select the height of a mountain or depth of a valley on the earth and set up a ratio with the approximate diameter of the earth. Compare the values for the two ratios.

3. Review the question of roundness and smoothness (step #1). Briefly discuss the results with students, as well as any problems that developed.

PRECAUTIONS:

1. Students must be able to transfer between a mathematical and physical model. This is difficult for many students, but it is an important objective of the course. Individual assistance will be needed by many students.

2. Accuracy is extremely important if you really want to prove that the earth is rounder and smoother than a globe; an experimental error of 3-4 mm. will yield misleading results based upon experimental error rather than on actual differences. The measuring instruments must be capable of measuring to the nearest mm. Be careful of most types of string since they usually stretch several mm. when pulled tight.

TYPICAL RESULTS:

	ROUNDNESS	SMOOTHNESS
GLOBE	$\frac{\text{Polar diam.}}{\text{Equat. diam.}} = \frac{20.2\text{cm.}}{20.4\text{cm.}} = .990$	$\frac{\text{Relief height}}{\text{Approx. diam.}} = \frac{0.5\text{mm.}}{202\text{mm.}} = .0025$
EARTH	$\frac{\text{Polar diam.}}{\text{Equat. diam.}} = \frac{12714\text{km.}}{12756\text{km.}} = .997$	$\frac{\text{Height of Everest}}{\text{Approx. Equat. diam.}} = \frac{8.8\text{km.}}{12{,}800\text{km.}} = .0007$

REFERENCES:

Investigating the Earth, pp. 70-73, Teacher's Guide, pp. 106-108. 117
Exploring Earth Science, pp. 156-157
Focus on Earth Science, pp. 24-28

III-A-2b: ROUNDNESS AND SMOOTHNESS

QUESTION:

How can the earth's shape be determined?

INTRODUCTION:

The earth, whose shape is usually referred to as round, is in fact not perfectly round as the following data indicates:

EARTH DATA

Polar diameter (accepted)	12,714 km.
Polar diameter (approximate)	12,700 km.
Equatorial diameter (accepted)	12,756 km.
Equatorial diameter (approx.)	12,800 km.

(Height of Mt. Everest 8.8 km.)

If the earth is not round, how much out of round is it? For example, which do you think is rounder, the earth or a globe? Which is smoother? In this investigation you are to devise a method for answering these questions.

OBJECTIVES:

When you finish this investigation you should be able to:

1. when given the polar and equatorial diameters of the earth and similar data for a model, determine which is roundest and defend your choice.
2. determine how high a relief feature of the earth would be on a model if constructed to scale given the following: the height of the feature on the earth, the diameter of the earth, and any necessary measurements on the model.
3. Choose from among several given models the one that best represents the true shape of the earth and defend your choice.

METHOD:

1. Determine a procedure by which you can measure and compare the roundness and smoothness of the earth with that of a globe.
2. Check with your teacher and, with approval, carry out your procedure. Be sure your measurements and calculations are accurate or your results will lead you to incorrect conclusions.

QUESTIONS:

(A-2.21) 1. How does the earth's circumference measured through the poles compare to its circumference measured along the equator?

(A-2.22) 2. Which is more nearly round, the earth or a globe? How do you know? (Support your answer with numerical data.)

3. Which is smoother, the earth of a globe? How do you know? (Support your answer with numerical data.)

4. How high would Mt. Everest (Elevation 8.8 km.) appear on your globe if constructed to true scale?

III-A-3a: OCEAN BOTTOM PROFILE

QUESTION:

What is the extent of the earth's atmosphere, hydrosphere, and lithosphere?

MATERIALS:

Graph paper, hand-out sheet with data tables.

SUGGESTED APPROACH:

1. Briefly discuss with the students the extent of the hydrosphere by asking them to study a globe and estimate the proportion of the earth's surface that is covered with water. Ask them how deep the oceans are compared to the diameter of the earth? Compared to the thickness of the atmosphere?

2. Discuss briefly determination of water depth by sonar. Sound travels at a rate of 4800 feet per second in water, so by timing how long it takes a sound to go from a ship to the bottom and back, it is possible to determine the depth of the water.

$$\text{depth in feet} = \frac{\text{time in seconds}}{2} \times 4800 \text{ ft./sec.}$$

3. Have the students make and label a profile of the ocean bottom by plotting depths against distance. Have them use true scale (i.e., no vertical exaggeration). In order to have any observable depth have them work in large groups and make the graph about 5-10 sheets long.

4. Lead the students in a discussion of the shape of the profile and the problems that developed in making it. Emphasize the thinness of the hydrosphere relative to its surface area. The students could also calculate the actual gradients of the continental shelf and slope and the average depth of the oceans in the area of the profile.

5. Using the measurement-of-squares technique, have the students estimate the percentage of the earth's surface covered by oceans.

PRECAUTIONS:

1. This exercise must be done to true scale or the value of it is lost. The students should realize that the ocean represents a relatively thin layer of water compared to its surface area.

REFERENCES:

Investigating the Earth, pp. 320-321
Our Planet in Space, pp. 488-496
Focus on Earth Science, pp. 210-215

III-A-3a: OCEAN BOTTOM PROFILE

QUESTION:

What is the extent of the earth's atmosphere, hydrosphere, and lithosphere?

INTRODUCTION:

How much of the earth's surface is covered with water? How deep is the water? What is the shape of the ocean bottom? In this investigation, you will make a profile of the ocean bottom which will help answer these questions and others.

OBJECTIVES:

When you finish this investigation you should be able to:

1. given distance and depth data, draw a profile of the ocean floor that illustrates the relief in true scale.
2. choose from among several given models the one that best represents the true shape of the ocean floor and defend your choice.

METHOD:

1. Using data given below, construct a profile of the ocean bottom. Connect sheets of graph paper end to end, plot distance on the horizontal axis and depth on the vertical axis. Be certain that you use the same scale on both axes since you want a true scale diagram.
2. By estimating the number of square centimeters of ocean compared to land on a globe, determine the approximate percentage of the earth's surface covered by water.

DISTANCE (Miles)	DEPTH (Miles)	LOCATION LANDMARK
0	0	Cape May
100	0.1	
125	1.0	
325	2.0	
475	2.5	
650	3.0	
900	2.8	
1125	2.9	
1300	3.1	
1425	2.9	
1475	2.0	
1600	1.6	
1900	2.5	
2000	2.1	
2150	1.8	
2200	1.2	
2225	0.8	North Atlantic Ridge
2325	0.7	" " "
2450	0.6	" " "
2475	0.0	Graciosa Island, Azores
2525	1.0	
2700	2.0	
2800	2.8	
3150	2.7	
3300	2.3	
3400	1.0	
3425	0.5	
3475	0.1	
3500	0	Cape Roca

Data are a series of depth soundings taken along the 39°N parallel from Cape May, New Jersey to Cape Roca, Portugal

QUESTIONS:

(A-3.21) 1. How deep are the oceans relative to the size of the earth?

(B-3.31) 2. What is the approximate percentage of the surface covered by water?

(B-3.31) 3. What was the maximum depth in cm. of the Atlantic Ocean drawn to the scale you used in this exercise?

III-B-1a: LOCATING POSITIONS

QUESTION:

How can a position on the earth's surface be determined?

MATERIALS:

Unmarked spheres (e.g. basketballs, volley balls, globes, plastic hemispheres).

SUGGESTED APPROACH:

1. Place a dot on one of the unmarked spheres and ask students to put a dot on their sphere at exactly the same location.
2. Briefly discuss with students the apparent problems resulting from step 1. Ask what else is needed to allow them to locate the point accurately.
3. Challenge the students to develop, on their spheres, a coordinate system that will allow them to locate positions. If most of them seem to feel constrained to use a latitude-longitude type grid, ask them if latitude-longitude is real or imaginary and therefore whether it's the only possible system; encourage them to use their imaginations.
4. Lead the students in a discussion of the systems they have devised. Develop from the discussion the basic requirements for a workable system.
5. Ask students to imagine that they have to set up their system on the real earth or moon; remind them that they obviously cannot hold these in their hands like the sphere and that this may result in some additional problems. Develop from this step the idea that to set up a coordinate system it is necessary to use observations of objects external to the earth, i.e. celestial objects as reference points.
6. Discuss the advantages and disadvantages of the latitude and longitude system with the students.

MODIFICATIONS:

1. Extend the idea of locating a position to the concept of time measurement by introducing the fact that the earth is a rotating sphere. Ask what system of time measurement might have developed if man used one of the student-developed systems of location. Would it be different?
2. Develop the idea that terms like top, bottom, up, down, east, west, are only relative.
3. Check student systems by having one student locate positions on a sphere using a system as directed by the student who designed the system.
4. Extend the concepts developed in the investigation to ideas about how man can locate positions in space. This is more difficult since a three dimensional system is required.

REFERENCES:

Investigation the Earth, pp. 63-66, Teacher's Guide pp. 96-100, 117-119.
Focus on Earth Science, p. 29.
Our Planet in Space, pp. 134-138.

III-B-1a: LOCATING POSITIONS

QUESTION:

How can a position on the earth's surface be determined?

INTRODUCTION:

We are continually using systems to describe positions of objects. The radio announcer uses a one-dimensional system to describe the position of the football on the field. The ship captain uses a two-dimensional system to describe his position at sea. The astronaut uses a three-dimensional system to describe his position. Each of these systems have some things in common, each is different in some respects. What general problems are involved in devising these systems? In this investigation you will be faced with some of these problems as you devise a system for locating positions.

OBJECTIVES:

When you have finished this investigation you should be able to:

1. develop a coordinate system to locate positions on a blank sphere.
2. given a sphere or a map with any coordinate system marked on it and a denoted position, determine the coordinates of the position.
3. explain the basis of the latitude-longitude system.

METHOD:

1. Locate on your sphere the position marked on your instructor's sphere.
2. Develop a coordinate system that will allow you to locate positions on a sphere more accurately.
3. Discuss your system with other students. Make a list of the basic requirements of any workable position-locating system. As a result of this list, make any changes in your system that you now feel are necessary.
4. Imagine now that you have to set up your system on the real earth. Determine the reference points you will use to establish your system. Keep in mind the list of basic requirements.
5. Compare your system with the latitude-longitude system used on the earth.

QUESTIONS:

1. What is the position-locating system that you have devised?

2. Using your system, what is the minimum information necessary to exactly locate a position on a sphere?

(B-1.11) 3. What are the basic characteristics of the latitude-longitude system?

(B-1.12) 4. What is the basis for the latitude-longitude system?

5. Explain how your system would have to be changed if the model were larger or smaller?

6. How would the latitude-longitude system have to be changed if the earth were larger or smaller?

Challenging (2.5)

III-B-2a: TEMPERATURE FIELD

QUESTION:

How can the characteristics of a position be measured and described?

MATERIALS:

Thermometers (at least 25), room plan maps (3 per student), fence diagram kit (optional).

SUGGESTED APPROACH:

1. Briefly discuss with students the nature of a field, have them give examples of fields, and then try to define fields based on these examples.
2. Have students distribute themselves around the room so that students are at each of the stations located on the blank maps. Each should have a thermometer.
3. After measuring the temperature at the floor, desk top level, and 1 meter above the desk top, the students should be prepared to report their data.
4. At least one student should be free to record data as it is called out by students around the room.
5. Each student should have the temperature data to be plotted for all the stations at three levels, i.e., he should have three maps. Have the students draw the isotherms according to their interpretations.
6. If you wish, have some of the students transfer their maps to a fence diagram; be sure they estimate the appearance of the isolines on the crosspieces.
7. Discuss with students the significance of the field and any problems they had in measuring and mapping the field. Have them locate on their maps the room's heat sources and sinks; have them predict what would happen if, for example, a window was opened (or closed); have them suggest some other fields that might exist in the room.

PRECAUTIONS:

1. Using a water bath, check the thermometers to see that they all record the same temperature. Those that do not should be labeled with a correction factor.
2. Check the room temperature at different levels in different parts of the room. You should detect at least a 2°C. range. If you do not, open a window, direct a heat lamp against one corner of the room, or adjust the heating system in some manner that will produce some variation.
3. To prevent thermometers from rolling, attach a spring-type clothespin to each.
4. If possible, have students read the temperature to the nearest 0.5°C.
5. Check students when they are constructing their maps to be sure they are drawing isotherms and not simply connecting all points that have the same value. Frequent errors include: allowing lines to cross, and omitting an interpolated value.
6. Because of the problems of drawing the isolines, be sure students use pencil.

TYPICAL RESULTS:

Results will vary depending on local climatic conditions and on the heating system of the room. A typical map will show a 2°-4°C temperature variation at any one level. Students will have difficulty in correctly drawing the isotherms, they will need help and constant reminding of the properties of an isoline.

MODIFICATIONS:

1. Measure the temperature field outside the classroom. Use the natural variation that exists due to shade or the presence of water. This would be a useful prelude to the study of weather and climate.

2. Use the school district for temperature analysis; allow the students to take thermometers home.

3. Since the purpose of this investigation is to allow students to become aware of the characteristics of a field, any kind of field can be used. For example, if light meters are available, a light intensity field can be measured. Another possibility is to have students bring in their pocket transistor radios and detect the field that surrounds power lines by means of the intensity of the static.

REFERENCES:

Investigating the Earth, pp. 106-107, Teacher's Guide pp. 149-152

III-B-2a: TEMPERATURE FIELD

QUESTION:

How can the characteristics of a position be measured and described?

INTRODUCTION:

What does the word "field" mean to you as it is used in the question? What are some examples of fields? What characteristics do all of these fields have in common? In this investigation you will measure and map the characteristics of a field.

OBJECTIVES:

When you finish this investigation you should be able to:

1. measure the temperature to the nearest half division at several locations within a temperature field.
2. plot field values on a map and draw isotherms.
3. prepare a three-dimensional model of the temperature field.
4. identify the isosurfaces within the field
5. locate heat sources and sinks within the field.
6. given a temperature field map, estimate the temperature at any given point.
7. given a temperature field map, indicate the areas of highest and lowest temperature, and the areas of maximum and minimum gradient.

METHOD:

1. At each station measure and record the temperature at the following elevations: floor level, desk-top level, and 1 meter above the desk.
2. Plot the measurements of temperature at each of the stations at floor level on a blank map of the room. Draw in the isotherms that must exist in the room at that level; remember that isotherms cannot cross and do not omit an isoline that must exist between two isolines even though no measurements were taken at those points.

3. Repeat step 2 for each of the other levels.

4. Transfer your three maps to the plastic sheets of the fence diagram kit. Sketch in the probable appearance of your map on the outside vertical cross pieces. Color the spaces between isotherms so that areas of the same temperature range are all the same color.

5. Compare your results with those of other students.

QUESTIONS:

(B-2.21) 1. How would you define a field?

(B-2.22) 2. Explain how field characteristics can be shown in two dimensions.

(B-2.23) 3. Explain how field characteristics can be shown in three dimensions.

(B-2.24) 4. Would the field you measured and mapped have the same appearance tomorrow? next week? next month? Explain.

(B-2.24) 5. How can the degree of change in field characteristics (gradient) be observed on a two-dimensional model?

6. What other fields do you think might exist in the room? How could you find out?

7. What factors do you think caused the variations in the room? How could you test to find out if you are correct?

8. Look at a U.S. weather bureau map.
What characteristics does it have that indicate it is a map of a field? How many fields are mapped on a weather map?

Easy (1.5.

III-B-2b: CONTOUR MAPPING

QUESTION:

How can the characteristics of a position be measured and described?

MATERIALS:

Plastic shoebox, landform model to fit inside shoebox, clear plastic sheet, marking pen, water.

SUGGESTED APPROACH:

1. Have the students make a contour map of the landform model by placing it in the shoebox, marking off equal divisions of depth on the side of the box, and then filling the box to the first line with water. The interface between land form and the water can then be traced. This should be repeated until the land form is completely covered with water. At this point the water can be poured out, and a plastic sheet placed on top of the shoebox top. Have the students look directly down at the model and trace the lines on the model on to the plastic sheet. The plastic sheet is now a contour map of the landform model.

2. Lead the students in a discussion of their contour maps. Emphasize that; contour lines are isolines; that altitude is a scalar field quantity; how areas of maximum and minimum elevation are shown; how areas of maximum and minimum gradient are shown; what contour interval means.

3. Have the students complete the exercise on the supplementary sheet for further map reading practice.

PRECAUTIONS:

1. The plastic landform models in the commercial contour model kits will float and may need to be fastened down with masking tape.

2. Use nonwater soluble pens when marking on the landform model; grease pens work well. However, water soluble marking pens are excellent for the plastic sheet.

MODIFICATIONS:

1. Add food coloring to the water and have the students draw the contour map on the plastic sheet directly without first marking on the landform model.

2. Have the students actually make a contour map of a small nearby hill. Simple surveying instruments can be easily constructed, especially if your school has a cooperative shop teacher.

3. If possible, use local maps and photographs of areas that will be used later in the course as field trip sites.

REFERENCES:

Investigating the Earth, pp. 76-79, Teacher's Guide, pp. 109-112, 117-119
Our Planet in Space, p. 441
Exploring Earth Science, pp. 400-421
Geology and Earth Sciences Sourcebook, pp. 365-376

III-B-2b: CONTOUR MAPPING

QUESTION:

How can the characteristics of a position be measured and described?

INTRODUCTION:

Maps are models. The kind of maps most often used by earth scientists are called contour or topographic maps. In this investigation, you will work with and make contour maps to determine how they portray the physical environment and to learn some of their advantages and disadvantages.

OBJECTIVES:

When you finish this investigation you should be able to:

1. match actual landforms and photographs of landforms with their map projections.
2. describe the properties of contour lines, and given some field data, determine whether it is scalar or vector.
3. given a topographic map, estimate the elevation at any given point.
4. given a topographic map, indicate the areas of highest and lowest elevation, and the areas of maximum and minimum gradient.

METHOD:

1. Place the landform model in the plastic shoebox. Mark the side of the box with equal divisions (1 centimeter is an appropriate division). Pour water into the box until the water level is at the first division mark. With the grease pencil, trace the interface between the water and the model. Repeat this until the water level is above the top of the model.
2. Pour out the water and put the top on the shoebox. Place a plastic sheet over the cover and trace onto the sheet the lines you just drew on the landform model. These lines on the sheet are called contour lines, the completed sheet is a contour map of the landform model.
3. Complete the topographic map exercise on the supplementary sheet.

QUESTIONS:

(B-2.21) 1. What is a field?

2. What field quantity does a contour map represent?

(B-2.22) 3. Explain how field characteristics can be shown in two dimensions.

(B-2.23) 4. Explain how field characteristics can be shown in three dimensions.

(B-2.24) 5. Would a field represented by contour lines be likely to undergo change with the passage of time?

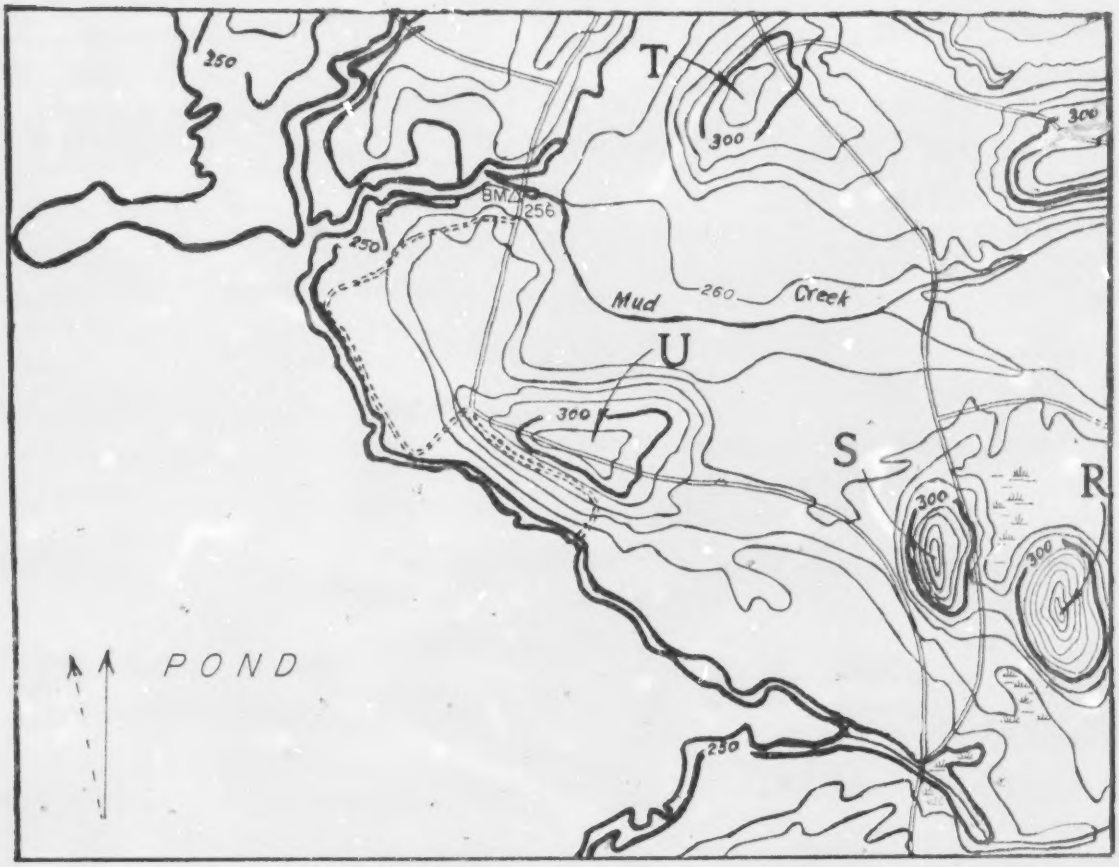
6. What information is necessary to make an accurate contour map?

(B-2.25) 7. How does a contour map show areas of steep gradient? low gradient?

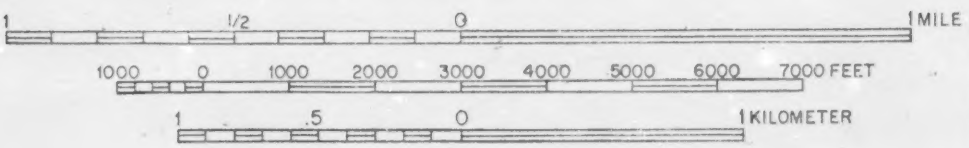
8. What characteristic shape does a valley have on a contour map? Explain how you could determine the direction of stream flow from a contour map.

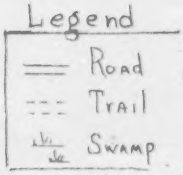
SUPPLEMENTARY SHEET

CONTOUR MAP EXERCISE



SCALE 1:24000





1. How far would you have to walk, in miles, if you followed the trail from where it leaves the highway, just below the BM 256 marker, to the point where it again joins the highway?

2. Which of the lettered hills has the highest elevation? What is it?

3. In what general direction does Mud Creek flow?

4. Which side of hill "T" has the least gradient?

5. What is the approximate elevation of the water in North Pond?

Easy (1)

III-B-2c: EARTH'S MAGNETIC FIELD

QUESTION:

How can field quantities of the earth be measured and described?

MATERIALS:

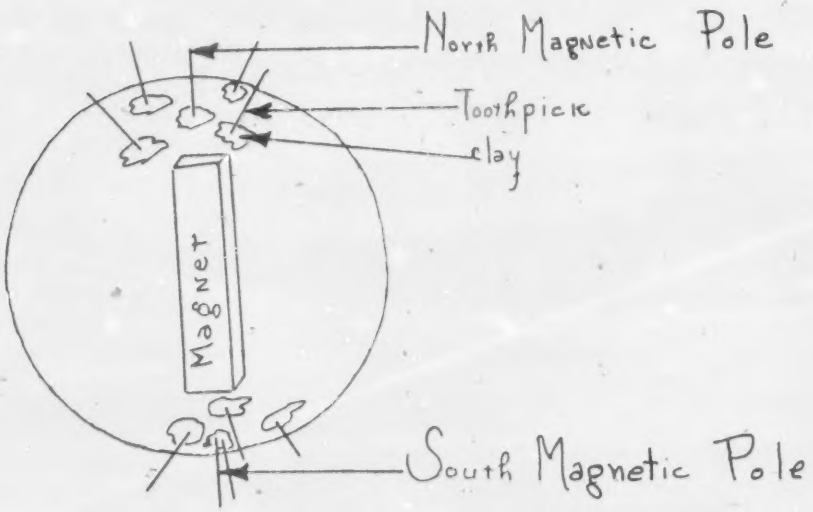
Compass, small magnet, globe (which can be taken apart), toothpicks, clay, topographic maps of several widely separated areas.

SUGGESTED APPROACH:

1. Tape a bar magnet to a disc which can then be taped into position within the globe. The position should not be divulged to the students. The orientation of the magnet need not represent the present position of the earth's magnetic poles.

2. Have the students locate the poles by rotating the sphere while holding a compass next to it. Be sure the compass is held horizontally so that the needle swings freely.

3. Have the students attach toothpicks to the sphere with clay in such a way that the orientation of the long axes of the toothpicks represent the shape of the magnetic lines of force at the surface of the sphere. See figure below for diagram of this step.



4. Lead the students in a discussion of the properties of the earth's magnetic field. Remind the students that, although only direction was measured, the magnetic field is vector in nature. Relate the field map to magnetic declination figures found on topographic maps. Compare the location and meaning of geographic and magnetic north poles.

PRECAUTIONS:

1. If compasses are placed on desks to keep them horizontal, be sure that there are no metal parts of the desk that will interfere with the magnet's field.

2. Be sure that the magnet has definite north and south poles.

MODIFICATIONS:

1. If the magnet is strong enough or the sphere small enough, the poles can be detected by having students lightly cover the bottom of a petri dish with iron filings and moving the sphere under the dish. The filings will react to the magnetic field by lining up in the direction of the field.

2. If clarification of the effect of a magnet on a compass is necessary, suspend a magnet and bring a horizontally-held compass near it from several different directions.

3. To illustrate a three-dimensional magnetic field, fill a large round-bottomed or Florence flask with glycerin or some other clear, viscous, nonreactive liquid. Add iron filings and shake. Set the flask on a strong horseshoe magnet. The filings will line up along the lines of force. This demonstration may be kept from year to year if the flask is kept stoppered.

4. To demonstrate magnetic declination, have students determine the direction of a high noon shadow and compare it to the compass direction at that point.

REFERENCES:

The Earth Sciences, Chp. 9, "The Earth as a Magnet"
Investigating the Earth, pp. 120-125, Teacher's Guide pp. 160-164, 169
Our Planet in Space, pp. 156-167
Exploring Earth Science, pp. 162-163

III-B-2c: EARTH'S MAGNETIC FIELD

QUESTION:

How can field quantities of the earth be measured and described?

INTRODUCTION:

Most of the fields you have studied have been ones that you can detect through your senses. However, there are some that you cannot detect directly because you have no specific sense for them. One of these field quantities is magnetism. In this investigation, you will measure and map a model of the earth's magnetic field.

OBJECTIVES:

When you finish this investigation you should be able to:

1. use a compass to describe the direction of the earth's magnetic field at any location.
2. describe the characteristics of the magnetic field model as they compare to the earth's magnetic field.
3. given the declination, use a compass to find the direction of of magnetic and true north.

METHOD:

1. Locate the magnetic poles on the earth model by holding a compass horizontally and rotating the sphere next to the compass.
2. Attach toothpicks to the sphere with clay in such a way that the long axes of the toothpicks represent the magnetic lines of force at the sphere's surface.
3. Discuss the characteristics of your model compared to the earth's magnetic field.
4. Look at the magnetic declination indicators on several topographic maps. Plot the declination direction on a blank U.S. map.

QUESTIONS:

(B-2.21) 1. What is a field?

2. What evidence indicates that magnetism is a field quantity?

3. Why can a compass be used to locate the poles?

4. Are magnetic lines of force a type of isoline? Why?

5. What is the relationship between the magnetic and the geographic north poles of the earth? Which one does a compass indicate?

6. Why do different locations have different magnetic declinations?

topic IV

What Are the Motions of the Earth?

Time Emphasis: 10 days

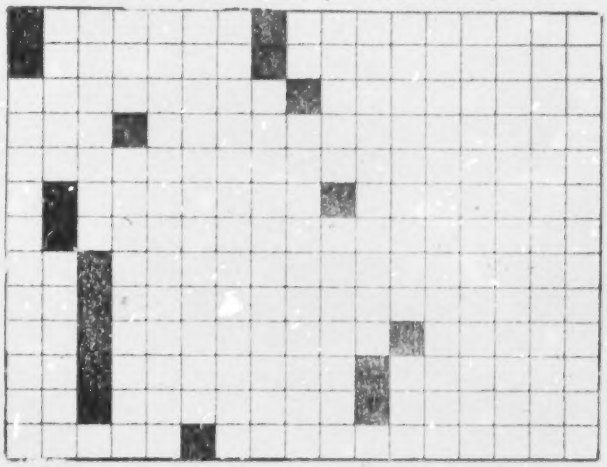
TOPIC OUTLINE

INVESTIGATION	A-1a	A-1b	A-1c	D-1a	D-1b	D-1c	D-2a	LTI - #6	LTI - #7	LTI - #8	LTI - #9	LTI - #10					
Estimated Time (Periods)	2	1+	1	1+	1	2	1										

A. Celestial observations

A-1 Motion of objects in the sky — *What Observations Can Be Made of Celestial Objects?*

- A-1.1 Star paths — A-1.11, A-1.12
- A-1.2 Planetary Motions — A-1.21, A-1.22, A-1.23
- A-1.3 Satellite motion — A-1.31, A-1.32
- A-1.4 Sun motion — A-1.41, A-1.42, A-1.43, A-1.44, A-1.45, A-1.46



B. Terrestrial observations

B-1 Motion at the earth's surface — *What Terrestrial Evidence Suggests Earth Motions?*

- B-1.1 Foucault Pendulum — B-1.11
- B-1.2 Coriolis Effect — B-1.21

C. Time

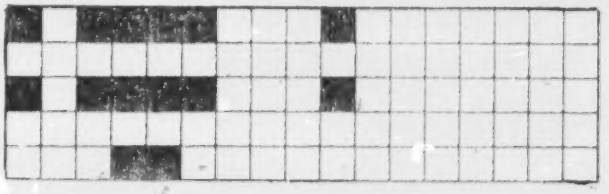
C-1 Frames of reference for time — *How Are Frames of Reference Determined for Time?*

- C-1.1 Earth motions — C-1.11, C-1.12

D. Solar system models

D-1 Geocentric and heliocentric models — *What Models Explain the Observations of Celestial and Terrestrial Motions?*

- D-1.1 Geocentric model — D-1.11, D-1.12
- D-1.2 Heliocentric model — D-1.21, D-1.22, D-1.23



Continued on next page

	INVESTIGATION	A-1a	A-1b	A-1c	D-1a	D-1b	D-1c	D-2a	LTI - #6	LTI - #7	LTI - #8	LTI - #9	LTI -#10					
	Estimated Time (Periods)	2	1+	1	1+	1	2	1										
TOPIC OUTLINE	D. Solar system models (continued)																	
	D-2 Simple celestial model *What Simple Celestial Model Can be Synthesized from Observations?*																	
	D-2.1 Geometry of orbits D-2.11						■											
	D-2.12							■										
	D-2.13							■										
	D-2.14																	
	D-2.2 Force and energy transformations D-2.21																	
	D-2.22																	
	D-2.23																	
	D-2.24																	
PROCESS OF INQUIRY OBJECTIVES	Mathematical Skill PIO-1	■	■			■	■				■							
	Measurement Skill PIO-2		■				■											
	Creating Models PIO-3		■				■											
	Analysis of Error PIO-4	■				■					■							
	Data Analysis PIO-5	■				■		■			■							
TITLES	Multimedia: Check Multimedia Section of Supplement for reference to this topic.	Celestial Observations	Moon's Path	Sun's Path Analysis	Planet Phases	Heliocentric & Geocentric Models	Solar Diameter	Orbits	Big Dipper	Planet	Moonrise-Moonset	Sunrise-Sunset	High Noon					

Difficult (2)

IV-A-1a: CELESTIAL OBSERVATIONS

QUESTION:

What observations can be made of celestial objects?

MATERIALS:

compass, star maps (optional), transparent hemisphere, water-color felt-tip pens, external protractor, astrolabe (or alternate procedure)

SUGGESTED APPROACH:

1. This investigation should be done individually during a 2-hour period on a clear evening during which three readings can be taken.
2. Briefly discuss the use of the star charts, if available, to help the student orient himself when he is observing the sky.
3. To check the student's plottings on the plastic hemisphere, place the position of the North star above the North Pole of a globe. The paths of all stars should be parallel to the lines of latitude.

PRECAUTIONS:

1. The student must observe the same stars at each of the different times.
2. All vertical angles must be measured from a true horizon rather than the local horizon.
3. Remind the students that the orientation of the plastic hemisphere must be the same each time that the stars are plotted.

TYPICAL RESULTS:

Some shift of position should be detectable for all stars. As the angular distance between the chosen star and the North star increases toward 90°, the linear displacement should increase.

MODIFICATIONS:

1. The entire exercise can be conducted with excellent results in a planetarium if one is available.
2. "Hand span method." Let each student devise his own, by holding his hand at a constant distance from his eye and sighting across it (e.g., from index to little finger), and scanning from horizon to zenith or around the complete horizon, he can calibrate his hand span. This method can be utilized in the absence of astrolabes.
3. Teachers should make the measurements in advance, anticipating the possibility of bad weather. Providing the student with the data is not as desirable as having him measure it, but in some cases this may be necessary.

4. Other alternative methods:

   a. Inv. 4-1, Investigating the Earth: Investigating motions in the sky watch.

   b. Have a star party preceding this exercise simply to get familiar with some of the more obvious constellations and bright stars.

   c. Photographic records: students with cameras may wish to take time photos of various portions of the sky. Students using high-speed film may take a succession of photos of the same portion of the sky and compare positions of stars on each.

REFERENCES:

Investigating the Earth, Teacher's Guide, pp. 123-126

IV-A-1a: CELESTIAL OBSERVATIONS

QUESTION:

What observations can be made of celestial objects?

INTRODUCTION:

In this investigation you will have an opportunity to observe and measure the positions of some stars in the nighttime sky. After having repeated your observations at different times during the night, you should look for patterns of change and attempt to explain them by devising a model.

OBJECTIVES:

When you finish this investigation you should be able to:

1. determine the location of north, south, east, and west in the nighttime sky.
2. measure the horizontal and vertical angles for objects in the sky.
3. describe the apparent movement of stars in various parts of the sky.

METHOD:

1. Determine the locations of north, south, east, and west at your observation point by using the North Star as the key reference point. Mark these directions in some way so that they can be referred to as the investigation progresses. If you cannot identify the North Star or the compass directions, select some landmark (e.g., tree, pole) on the horizon from which you can make measurements. Divide the sky into four sections based on your landmark reference.
2. Choose four stars that you can easily find again - one in each section of the sky. Mark these stars on the star map, if one is available.
3. Using the astrolabe or any alternate method, determine and record the horizontal and vertical angles for each of the four reference stars.

4. Repeat these readings for the same four stars 1 hour later, and a third time an hour after that. Make sure that you record the exact time for each set of the readings. Record each observation in the chart below.

5. Plot the values on the transparent hemisphere for each of the four sets of star readings. Use the water-color felt-tip pens and external protractor. Make sure that your orientation is the same as that used during the original readings.

	Time	Time	Time
Northern Star	VA	VA	VA
	HA	HA	HA
Southern Star	VA	VA	VA
	HA	HA	HA
Eastern Star	VA	VA	VA
	HA	HA	HA
Western Star	VA	VA	VA
	HA	HA	HA

VA = Vertical Angle (measured from the horizon)

HA = Horizontal Angle (measured from the North point or some suitable landmark on the horizon)

QUESTIONS:

1. What motions of the stars did you observe during the 2 hours of observation?

(A-1.11) 2. If you were to extend these motions over a 24-hour period, what shape path would be formed?

(A-1.12) 3. What was the rate of star motion during your period of observation?

4. Did any of the stars you observed shift position relative to each other? Explain.

(D-1.11) (D-1.21) 5. Based on your observations of the night sky, what are some possible causes for the motions you observed?

Easy (1+)

IV-A-1b: MOON'S PATH

QUESTION:

What observations can be made of celestial objects?

MATERIALS:

polar-coordinate (circular) graph paper, drawing compass

SUGGESTED APPROACH:

1. Students should work individually on the investigation.

2. The students should become familiar with angular measurement by use of the following exercise:

   Place a globe or some comparably shaped object in the front of the room. Have students hold a coin perpendicular to their line of sight and adjust its distance from their eye so that it just blocks out the shape of the globe. Have the students maintain their position and walk toward them carrying the globe in front of you. Ask the students to describe the apparent change observed in the globe's size (angular diameter).

   Illustrate to the students that the angular diameter of an object could change as a result of an actual change in the size of the object, with or without a distance change.

3. A brief discussion should follow emphasizing the relationship of the apparent change in angular diameter to the moon's distance from the earth. This discussion may be directed at the relationship evident in Columns 3 and 4 in the table found on the student sheet. (The values in Column 4 were derived by multiplying the reciprocal value of angular diameter (in seconds of arc) by a constant 1.25×10^6.)

4. Special emphasis should be applied to the discussion following the completion of this investigation. The answers to the student questions and the ensuing discussion should aid in gaining a better understanding of the relationship between the earth, moon, and sun.

PRECAUTIONS:

1. The student may need assistance in using the circular coordinate graph paper. Remind the student that the two coordinates on this type graph paper are distance from the center and angle.

2. Use a scale such that each circle on the graph represents 100 units of the distance between the earth and moon.

MODIFICATIONS:

If available, use the actual data for the sun and moon for the month in which the unit is taught. If this is done students can be instructed to make observations of the phases to coordinate with the predictions from the activity.

REFERENCES:

Investigating the Earth, p. 482, Teacher's Guide, pp. 611-614

IV-A-1b: MOON'S PATH

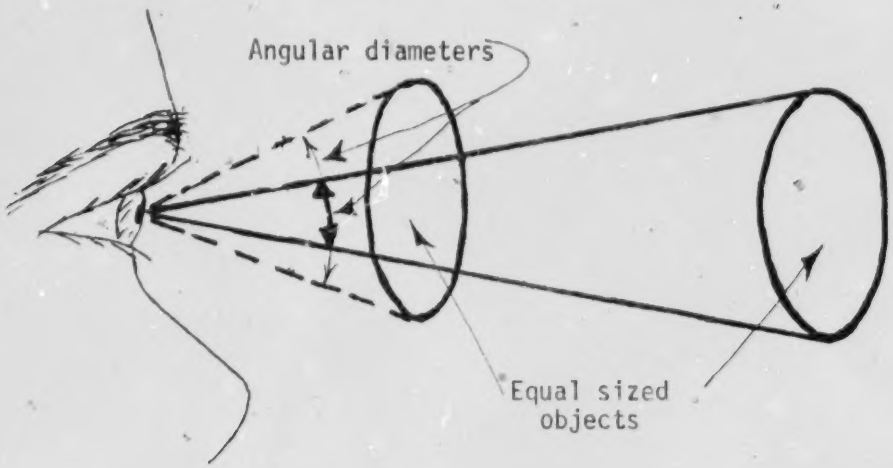
QUESTION:

What observations can be made of celestial objects?

INTRODUCTION:

The moon is very often the brightest object in the night sky, yet it appears to change in appearance with regularity. Using the data concerning the moon's position, distance and appearance, you will investigate this change.

The angular diameter of an object is determined by measuring it, apparent width in degrees (see diagram).



The angular diameter of an object can be measured without reference to distance. However, a change in angular diameter of an object means either the distance between you and the object is changing or the actual size of the object is changing.

OBJECTIVES:

When you finish this investigation you should be able to:

1. plot lunar positions relative to the earth, given appropriate data on polar graph paper.
2. indicate the lunar phase given the relative positions of the sun, earth, and moon

METHOD:

1. Plot the data from the chart below on the polar graph paper.

2. Plot the earth at the center of the graph. Plot the location of the moon, in relation to the earth, for each day shown in the data chart.

3. Because the sun's distance is much greater than the moon's distance, show its position with an arrow indicating the direction the sun's rays are traveling toward the earth for that date.

Date	Celestial* Longitude of Moon	Angular Diameter of Moon	Distance from Earth	Celestial* Longitude of Sun
May 1	185°	33.1'	629	40°
3	215	33.2	628	42
5	244	32.6	638	44
7	273	31.7	657	46
9	299	30.7	678	48
11	324	30.0	695	50
13	348	29.5	705	52
15	12	29.5	707	54
17	36	29.7	702	56
19	60	30.0	693	57
21	85	30.5	682	59
23	111	31.1	670	61
25	138	31.7	657	63
27	166	32.3	645	65
29	195	32.7	637	67
31	224	32.8	636	69

*Celestial longitude is the angle measured clockwise from some reference point to the object.

QUESTIONS:

(A-1.32) 1. How could you best describe the pattern of change of the moon's angular diameter over a long period of time?

2. If, as in the Figure, the observer remains stationary:

   a. How would the angular diameter of the sphere change if it were one-half the distance shown in the diagram?

   b. What do you think is the relationship between the earth-moon distance and the moon's angular diameter as measured from the earth?

(A-1.31) 3. Indicate on the graph where the moon will be when it is in:

a. Full phase

b. Quarter phase

c. New phase

4. At what locations might lunar eclipses occur?

5. Since the sun appears to shift approximately 30 degrees each month, where will the next full moon be? Locate it on the graph.

6. The moon's period of revolution is 27.3 days. What is the time from one full moon to the next?

7. How does the moon's orbit compare to a circular path?

IV-A-1c: SUN'S PATH ANALYSIS
(Continuation of LTI #3 - Sun's Path)

QUESTION:

What observations can be made of celestial objects?

MATERIALS:

metric ruler, string, protractor (external or internal protractor if available), graph paper

SUGGESTED APPROACH:

1. Have the students analyze the data collected during "The Sun's Path - Long Term Investigation" as indicated on the student sheet.
2. Have the students do the supplementary sheet exercise as a homework exercise.
3. Conduct a discussion after completion of the student investigation. Consider topics such as, "What model or models explain the observations made in this investigation."

BACKGROUND INFORMATION:

1. To determine the number of hours of daylight: Measure the distance (d) along the base of the hemisphere between the sunrise and sunset points. This is the projection of the sun's path in the horizontal plane.

   Compare distance (d) with the circumference of the hemisphere (c) which is the projection of the entire 24-hour path of the sun.

   Use the equation: $\frac{d}{c} \times 24 \text{ hrs.} = L$ (length of day expressed in hours). Solve for L.

2. To measure the sun's motion expressed as angular distance per hour: Use the equation: $\frac{d}{c} \times 360^\circ = \phi$ (degrees covered during daylight hours). Solve for ϕ.

   Use the Relationship $\frac{\phi}{L} = A$ (angular distance per hour). Solve for A.

3. To measure direction of sunrise and sunset, use a protractor and measure the angle between the north line and the sunrise and sunset points along a horizontal plane. This can then be translated into a directional bearing (i.e., 5° north of east).

IV-A-1c: SUN'S PATH ANALYSIS

(Continuation of LTI #3 - Sun's Path)

QUESTION:

What observations can be made of celestial objects?

INTRODUCTION:

The sun has always been of prime importance to men. Long before it was clearly understood that the sun was indeed the primary energy source for the earth, men knew of some of the effects of sunlight on their lives. The rising and setting of the sun provided a natural rhythm for man's daily activities. The seasonal changes in the intensity and duration of sunshine regulated growing seasons. Because his life was so organized around the behavior of the sun, man came to realize the regularity and predictability of the sun's actions.

OBJECTIVES:

When you finish this investigation you should be able to:

1. determine the number of hours of daylight, given a hemisphere containing a plot of the sun's path for a day.
2. determine the number of degrees the sun moves per hour, given a hemisphere containing a plot of the sun's path for a day.
3. determine the direction of sunrise and sunset, given a hemisphere containing a plot of the sun's path for a day.
4. identify the appropriate season, given a plot of the sun's path for a day in either summer or winter.

METHOD:

1. Analyze the data collected during the "Sun's Path Long-Term Investigation" for the following information:
   a) length of day (expressed in hours) for each path;
   b) angular distance per hour that the sun moved for each path;
   c) comparison of heights of noontime sun on different dates;
   d) compass direction of sunrise and sunset for each path.
2. Compare each of the above observations with the season during which it occurred and list inferences that you can draw from the evidence.

QUESTIONS:

(A-1.41) 1. What is the shape of the apparent path of the sun through the sky?

(A-1.42) 2. How does the apparent path change with the seasons?

3. What is the approximate angular distance the sun moves in one hour? How does this vary with the seasons?

4. What was the angular distance of the sun above the southern horizon at midday? What do you think will happen to this angular distance during the course of the school year?

(A-1.45) 5. How does the length of the sun's path vary with the seasons? How will this affect the length of day?

(A-1.43) 6. What evidence do you have to prove or disprove the following statement: "The sun is directly overhead at noon"?

(A-1.44) 7. What evidence do you have to prove or disprove the following statement: "The sun always rises in the east and sets in the west"?

(D-1.11)
(D-1.21) 8. What are some models of motions in the earth-sun system that can explain the observations made in the investigation?

SUPPLEMENTARY SHEET #1

ANALYSIS OF HIGH NOON OBSERVATIONS

Observations of the sun were made each week for one year. Measurements of the maximum altitude of the sun were taken. The time of day at which the maximum altitude occurred was also noted.

The table contains the observations as recorded on the days listed.

Draw a graph of the data in the table using coordinates of altitude on the vertical axis and time the horizontal axis. Each point represents where the sun was at "high noon" on the particular day.

Date	Maximum Altitude of the sun degrees	minutes	Time of Maximum Altitude
Jan. 1	24	54	12:03
8	25	37	12:06
15	26	40	12:09
22	28	04	12:11
29	31	46	12:13
Feb. 5	32	44	12:14
12	33	56	12:14
19	36	19	12:14
26	38	52	12:13
Mar. 4	41	30	12:12
11	44	14	12:10
18	47	00	12:08
25	49	45	12:06
Apr. 1	52	29	12:04
8	55	09	12:02
15	57	43	12:00
22	60	09	11:58
29	62	25	11:57
May 6	64	30	11:56
13	66	21	11:56
20	67	56	11:56
27	69	16	11:57
June 3	70	18	11:58
10	71	00	11:59
17	71	23	12:01
24	71	25	12:02

Date	Maximum Altitude of the sun degrees	minutes	Time of Maximum Altitude
July 1	71	07	12:04
8	70	30	12:05
15	69	33	12:06
22	68	19	12:06
29	66	48	12:06
Aug. 5	65	01	12:06
12	63	02	12:05
19	60	50	12:03
26	58	28	12:02
Sept. 2	55	58	12:00
9	53	23	11:57
16	50	42	11:55
23	48	00	11:52
30	45	26	11:50
Oct. 7	42	34	11:48
14	39	55	11:46
21	37	22	11:45
28	35	56	11:44
Nov. 4	32	40	11:44
11	30	37	11:44
18	28	49	11:45
25	27	17	11:47
Dec. 2	26	04	11:50
9	25	12	11:52
16	24	42	11:56
23	24	34	11:59
30	24	40	12:03

QUESTIONS:

(A-1.43) 1. a. What was the maximum altitude observed?
b. When did the maximum occur?
c. What was the minimum altitude observed?
d. When did the minimum occur?

(C-1.11) (C-1.12) 2. a. How does clock time (noon) compare with solar time (solar noon) for the year?
b. Describe the variations between the times.

(D-1.11) (D-1.21) 3. What model can you devise to explain this evidence?

Easy (1+)

IV-D-1a: PLANET PHASES

QUESTION:

What models explain the observations of celestial and terrestrial motions?

MATERIALS:

Small incandescent light source, small ball such as a ping-pong ball or styrofoam sphere to represent planet X, photos of phases of Venus. (Optional)

SUGGESTED APPROACH:

1. A student grouping of two is recommended for this investigation.
2. A brief discussion may be required in order that the ball, light, and observer be identified as planet, sun, and earth respectively. From that point on, the students are to investigate possible ways to create the phases of planet X, as described in the introduction on the student sheet.
3. The photos of Venus may be used after the students have had a good deal of time to work with the problem.

PRECAUTIONS:

1. You must have a sharp, bright light source or the phases will not be evident to the students.
2. The darker the room, the easier it is to see the phases.
3. Do not label models of the solar system such as heliocentric or geocentric to begin with. After the investigation is complete you might label several of the models proposed.
4. Remember planet X is not conclusive proof of the heliocentric model. It would serve to cause serious doubt on the Ptolemaic version, but would not necessarily discredit Tycho Brahe's scheme. Perhaps one of your students will want to show the rest of the group why not.

MODIFICATIONS:

1. Use photos of a superior planet, and have the students relate any differences that they see in the two planets.
2. For more complete analysis, use questions from the reference below.

REFERENCES:

Investigating the Earth, pp. 497-498, Teacher's Guide, pp. 629-631.

IV-D-1a: PLANET PHASES

QUESTION:

What models explain the observations of celestial and terrestrial motions?

INTRODUCTION:

There is a certain planet which is always observed just before sunrise or just after sunset. It never wanders far from the sun. Sometimes it is observed on successive evenings to have moved eastward among the stars. It reaches a maximum distance from the sun (greatest eastern elongation) and begins to move westward among the stars. One of the first discoveries made with a telescope was that this planet exhibits phases similar to those of our moon. However, the apparent size of the planet is least during full phase and greatest at crescent phase as shown in the diagram below.

OBJECTIVES:

When you finish this investigation you should be able to:

1. describe a model for an earth-sun-planet X system that will satisfactorily explain the observation of a planet.

METHOD:

1. Use the light (sun) and small ball (planet X) to simulate the actual observations of planet X.
2. Devise a diagram or description which will explain the results of your simulation.

QUESTIONS:

(D-1.11) (D-1.21) 1. What models of the earth-sun-planet X system can you devise to explain the observations made during this investigation?

(D-1.23) 2. Which model for the earth-sun-planet X system best explains the observations?

(A-1.22) 3. What is the pattern of changes observed in planet X over a long period of time?

4. What is the relationship between the orbit of planet X and that of the earth?

5. Which planet is planet X?

6. What could be a possible cause for the difference in appearance between the phases of the moon and planet X?

7. How would a planet, orbiting between the earth and sun, differ in appearance from a planet at a greater distance from the sun than the earth?

Challenging (1)

IV-D-1b: HELIOCENTRIC, GEOCENTRIC MODELS

QUESTION:

What models explain the observations of celestial and terrestrial motions?

MATERIALS:

Data table containing observations of planet X and planet Y, diagrams for heliocentric and geocentric models, protractor, straightedge.

SUGGESTED APPROACH:

1. Initiate a discussion with the students about the motions of the planets, sun, and earth.
2. Most students contend that the earth and planets are moving around the sun. Challenge their belief by asking what evidence they can offer to prove their contentions.
3. Discuss the types of evidence that can be observed, namely positions of the celestial objects and apparent size.
4. Discuss possible means of measuring the angle between a planet and the sun. Review the data in previous investigations about measuring changing diameters.
5. Have the students select either planet and then plot its apparent motion in both systems, heliocentric and geocentric. It is suggested that this step be completed as a homework assignment.
6. In the follow-up discussion, the two resulting paths for each planet should be compared. Ths students should evaluate each model for its simplicity in representing the paths.

PRECAUTIONS:

1. The students will probably experience some difficulty in plotting the first few points. Be sure they understand that heliocentric plots are made from the various points on the circle, the geocentric ones from the center.
2. Both paths of planet Y will extend beyond the paper. Students can add extra sheets of blank paper to continue the path. The geocentric path of planet X will also extend beyond the paper.

TYPICAL RESULTS:

If the students connect the points with a smooth curved line, a complex figure will result with both geocentric models. The heliocentric models will result in reasonably smooth circular paths. The average distance from the planets to the sun can be calculated and should result in an identification of planet X as Venus and planet Y as Mars. The students can make a tentative identification of the planets based on this evidence.

MODIFICATIONS:

1. Have the students make observations of planets and devise a system for measuring the angle between the planet and the sun.
2. Have the students consider the problem of plotting the moon's position in a manner similar to that used for the planets.

IV-D-1b: HELIOCENTRIC, GEOCENTRIC MODEL

QUESTION:

What models explain the observations of celestial and terrestrial motions?

INTRODUCTION:

Does the earth move with the planets around the sun, or do the planets and sun move around the earth? You most likely contend that the former scheme is the true one, but what is the basis for your contentions? Some observational evidences that we can gather easily to prove one scheme or the other are: 1) relative positions of the planets and the sun; 2) apparent sizes of the celestial objects from which a relative distance may be inferred.

Two planets were carefully observed for a 2-year period. Measurements of their positions and apparent distances were made for each month.

OBJECTIVES:

When you finish this investigation you should be able to:

1. measure angles and distances in plotting experimental data to an accuracy of one half of the smallest scale divisions of the protractor and distance scale.
2. devise a heliocentric or geocentric model for the observations of a planet.
3. evaluate heliocentric and geocentric models for planetary motion to determine which provides the simpler explanation of the observations.

METHOD:

1. Use the data in the table below to create a model for the motions of one of the planets. You may use either planet, but plot both a sun-centered (heliocentric) and an earth-centered (geocentric) model for the planet chosen. Which one will best explain the observations?

   A. Heliocentric model: Use the diagram for the heliocentric model that shows the sun at the center of the earth's path over the 2-year period. Plot the position of the planet for each date, making your measurements from the earth's position in each case. Connect the points with a smooth line.

B. Geocentric model: Use the diagram for the geocentric model that shows the earth at the center of the sun's path over a 2-year period. Plot the position of the planet for each date, making your measurements each time from the center, the earth's position. Note carefully that each time the sun is in a different location. Connect the points with a smooth line.

When you are locating the points, draw construction lines lightly so that they may be erased after the point is plotted.

2. The first date for planet X has been plotted as an example.

3. Analyze the two models and determine the average distance of the planet from the sun.

4. Determine the minimum amount of time (in months) for the planet to make one revolution.

QUESTIONS:

1. What is the average distance from the sun for the planet you plotted?

2. What is the minimum amount of time (period) for the planet to make one complete revolution?

(D-1.11) (D-1.21) 3. Which model satisfactorily explains the observations of the planets?

(D-1.23) 4. Which model seems to be a simpler explanation of the observations?

5. On the basis of the evidence and your analysis, what planet of the solar system did you plot?

SUPPLEMENTARY SHEET 1

CELESTIAL OBSERVATIONS OF PLANET X AND PLANET Y
DURING 1966 AND 1967
(Taken on the 15th day of each month.)

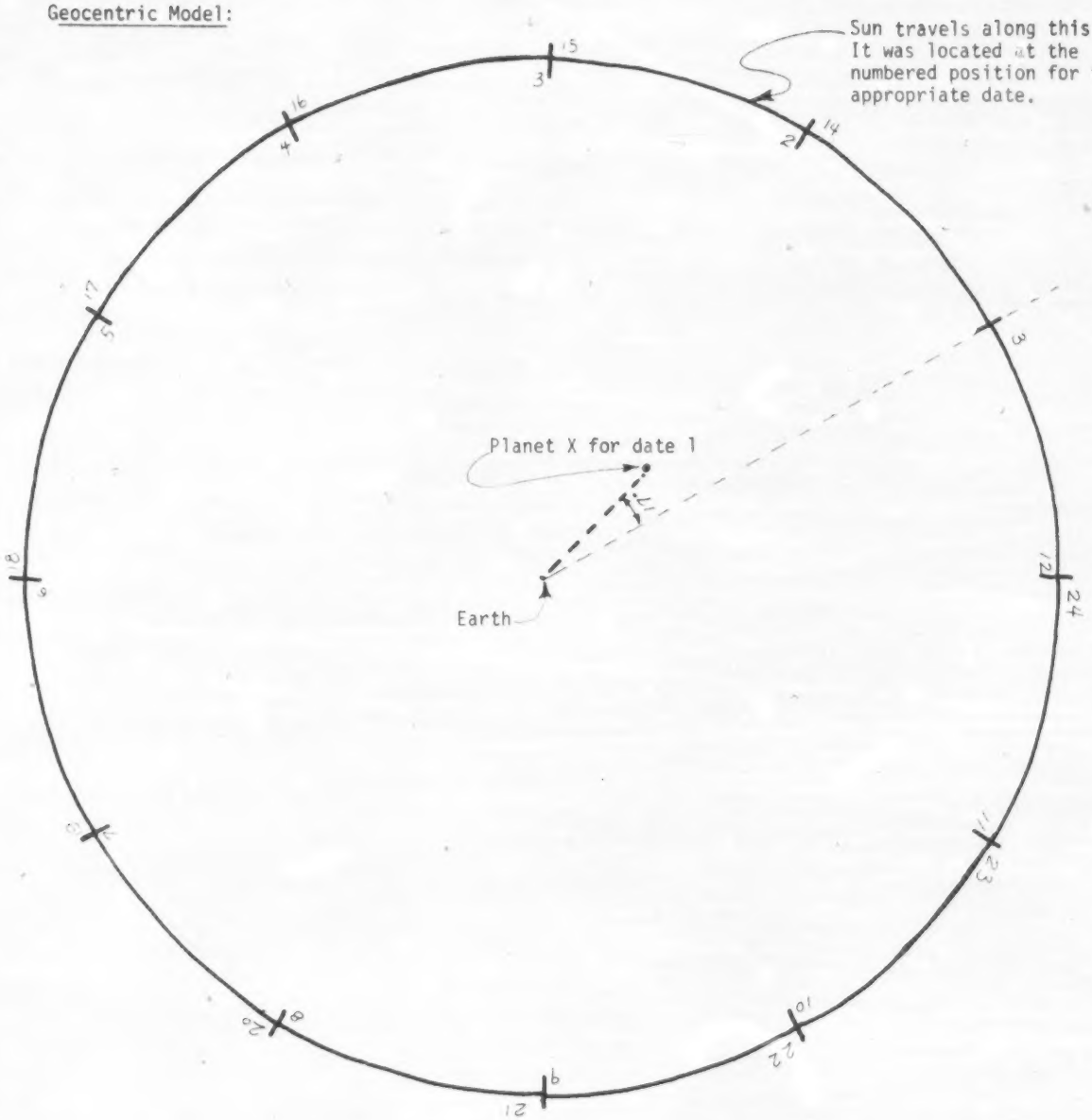
Date (Month)	Planet X		Planet Y	
	Angle of Elongation (degrees)	True Distance from Earth (A.U.)	Angle of Elongation (degrees)	True Distance from Earth (A.U.)
1	+17.0	.28	+ 24.5	2.23
2	-29.3	.33	+ 16.0	2.31
3	-43.1	.51	+ 9.7	2.37
4	-42.8	.75	+ 3.3	2.43
5	-40.6	.98	- 3.8	2.48
6	-38.0	1.21	- 12.3	2.49
7	-32.6	1.39	- 21.0	2.47
8	-22.6	1.54	- 21.1	2.40
9	-13.0	1.65	- 36.8	2.27
10	- 5.2	1.70	- 45.5	2.10
11	+ 1.8	1.71	- 57.7	1.86
12	+ .9	1.68	- 76.0	1.62
13	+17.3	1.62	- 96.5	1.28
14	+22.5	1.52	-118.5	.97
15	+27.2	1.39	-142.5	.74
16	+35.8	1.21	-178.5	.61
17	+45.0	1.00	+144.0	.65
18	+49.0	.75	+113.3	.81
19	+42.5	.51	+ 91.8	1.00
20	+18.3	.32	+ 77.3	1.19
21	-24.5	.32	+ 68.8	1.37
22	-41.0	.50	+ 64.3	1.53
23	-44.0	.73	+ 59.2	1.69
24	-44.5	.95	+ 51.3	1.83

Angle of elongation: The angle between the sun and the planet.
+ means the angle is measured counterclockwise
- means the angle is measured clockwise

A.U. (Astronomical Unit): The average distance between the earth and the sun is 1 A.U.

SUPPLEMENTARY SHEET #2

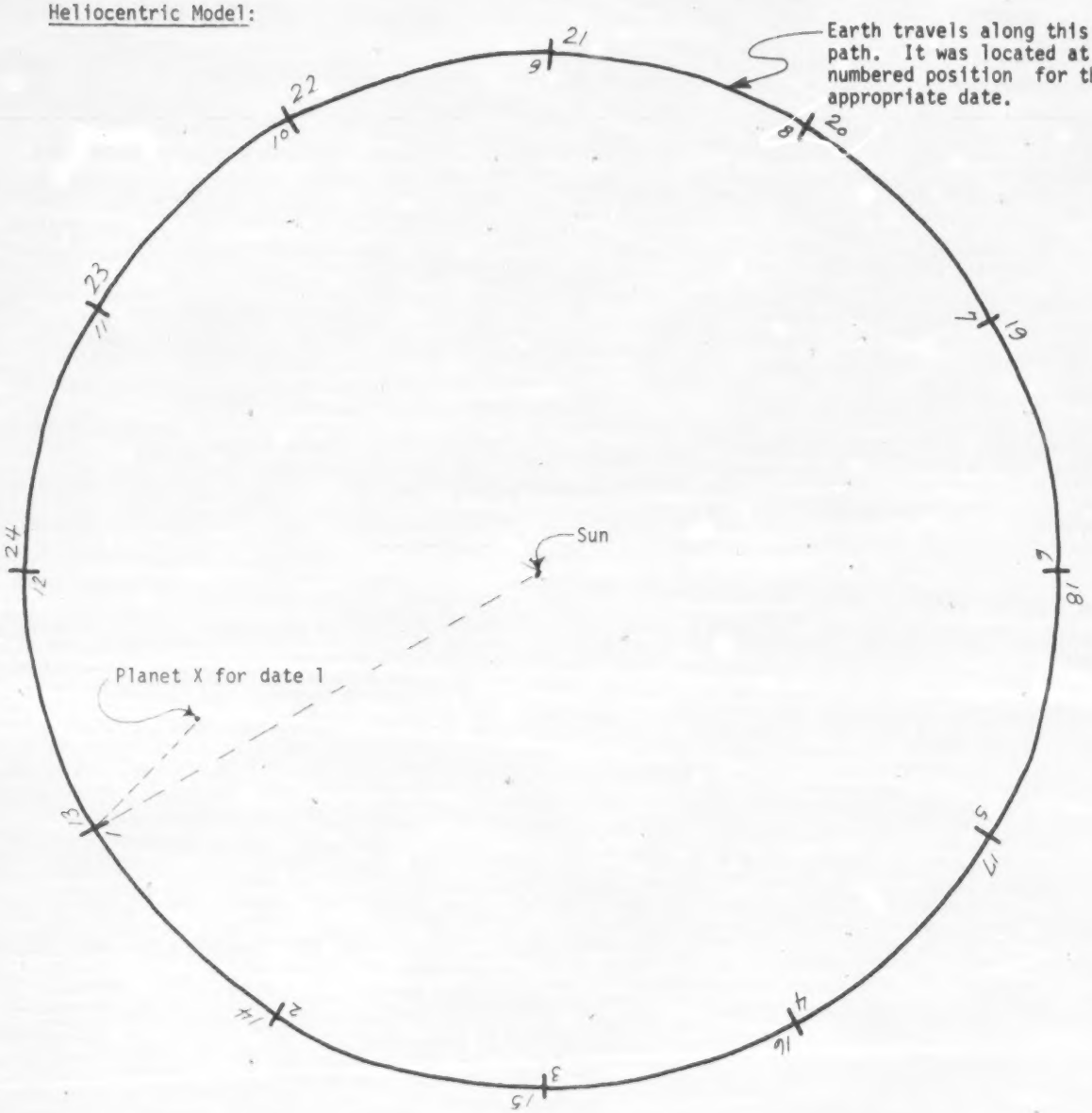
Geocentric Model:


Sun travels along this path. It was located at the numbered position for the appropriate date.
Planet X for date 1
Earth
0 .1 .2 .3 .4 .5 .6 .7 .8 .9 1.0 1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8 1.9 2.0

SCALE IN ASTRONOMICAL UNITS
(to be used in plotting position of planets)

SUPPLEMENTARY SHEET #3

Heliocentric Model:


Earth travels along this path. It was located at the numbered position for the appropriate date.
Sun
Planet X for date 1
0 .1 .2 .3 .4 .5 .6 .7 .8 .9 1.0 1.1 1.2 1.3 1.4 1.5 1.6 1.7 1.8 1.9 2.0

SCALE IN ASTRONOMICAL UNITS
(to be used in plotting position of planets)

Challenging (2)

IV-D-1c: SOLAR DIAMETER

QUESTION:

What models explain the observations of celestial and terrestrial motions?

MATERIALS:

1 meter stick, 2 opaque lined cards (one 8 X 10" and the other 4 X 6"), 1 pair of scissors, drawing compass, graph paper, solar diameter data (student sheet).

SUGGESTED APPROACH:

This investigation consists of two parts. Part I involves actual measurement of the sun's angular diameter. Part II consists of plotting a graph from the data table which is provided for the students. Part II may be done in class, or more preferably, as a homework assignment.

Part I

1. This investigation is best accomplished with a student grouping of two or three.
2. Have the students assemble the apparatus as indicated on the student sheet.
3. Have the students make the necessary measurements and calculate the angular diameter of the sun.

Part II

4. This investigation can be accomplished individually within a 40-minute period or as a homework assignment.
5. Have the students plot a graph of the data from the supplementary sheet.
6. In order to allow better comparisons during the post-laboratory discussion it will be necessary to establish some uniform scale for the students' graphs.
7. The discussion concerning interpretation of the graphs should be centered around the nature of the orbit. A lively discussion usually ensues if the teacher takes the position that the sun revolves around the earth and supports it with observations made during the investigation.

PRECAUTIONS:

Part I

1. Do not allow the students to look directly at the sun which can damage their eyes.
2. Make sure that the students keep the cards perpendicular while making all observations and measurements.
3. A small circle (.5-.8 cm. dia.) can be drawn on the small card which is then moved until the image fills it. However, construction of such a circle is difficult and it may be desirable to use parallel lines instead as suggested in the approach.

Part II

4. The main objective of the investigation is to demonstrate the use of angular measurement as indirect evidence of the nature of the earth-sun orbit. Students should not be allowed to dwell on the mechanics of the lab to the point where they lose sight of its main objective.

TYPICAL RESULTS:

The students' graphs in Part II should illustrate the cyclic change in angular diameter of the sun. The students should be able to relate the change in diameter to the distance of the sun and defend possible earth-sun models which would support their observations. Some students may interpret the change in diameter as an actual change in size. From the data provided this cannot be disproved.

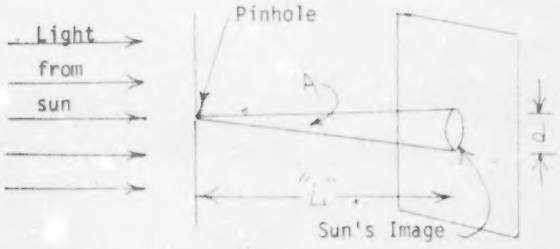
MODIFICATIONS:

1. Old mailing tubes can be used in place of the apparatus suggested above. Aluminum foil with a pinhole and a translucent screen for viewing can be fastened to opposite ends of the tube.
2. Use the same basic apparatus as in Part I to measure the angular diameter of the full moon.
3. Given the diameter of the sun, find the distance to it.
4. As a subsequent activity to Part II, the students might take data collected for other years, graph them, and compare the results to 1967.

BACKGROUND INFORMATION:

Students should express the measurement of the sun's diameter as an angle. The size of the angle can best be described by use of radian measure. The following diagram may help to describe the use of radian measure in determining the angular diameter of the sun.

Figure 1

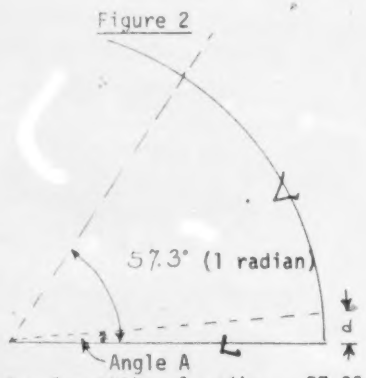


A = angular size of image

d = diameter of the image

L = distance from pinhole to screen

Figure 2



Arc length L = 1 radian = 57.3°

Angle A $= \frac{d}{L}$ radians

Angle A $= \frac{d}{L} \times 57.3$

REFERENCES:

Investigating the Earth, p. 530

IV-D-1c: SOLAR DIAMETER

QUESTION:

What models explain the observations of celestial and terrestrial motions?

INTRODUCTION:

Measurement of the distance to the sun or its diameter are difficult to determine since many variables are involved. However, the angular diameter of the sun can be determined with considerable accuracy. In this investigation, you will have an opportunity to measure the angular diameter of the sun and analyze similar data to look for patterns of change.

OBJECTIVES:

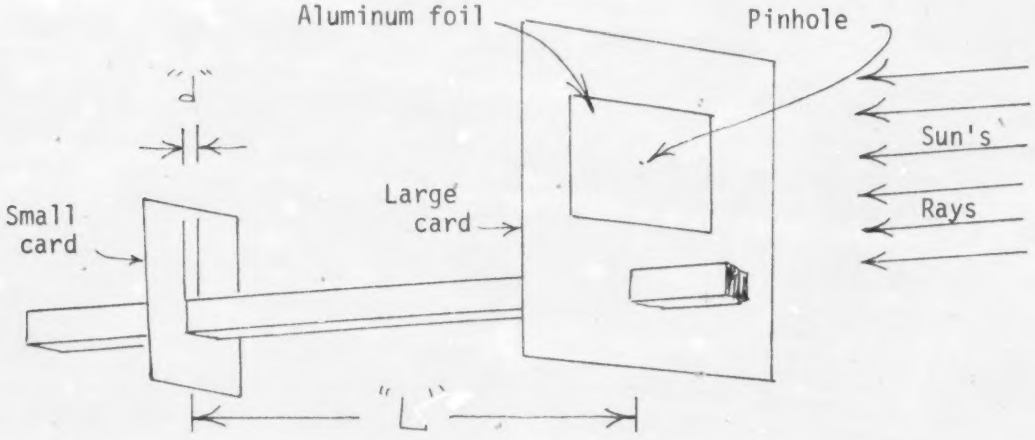
When you finish this investigation you should be able to:

1. calculate the angular diameter of the sun from measurements you have made, when provided with the necessary equipment.
2. draw a graph which represents angular measurements of an object.
3. propose and defend possible models of the earth-sun motions based on the observed change in angular measurements.

METHOD:

Part I

A. Assemble the apparatus as shown below.



a. Cut slots in each of the cards, in the position shown, so that the meter stick can fit through them. Each slot should be slightly smaller than the width and breadth of the stick to ensure a tight fit.

b. If the small card is unlined, draw two parallel lines .8 cm. apart as shown.

c. Make a large hole in the largest card, cover it with aluminum foil, and then punch a very small hole through this with a compass point or pin.

B. Place the large card near the end of the meter stick and move the small card until the image of the sun just fills the space between the two lines.

C. Measure (to the nearest 1/10 cm.) the distance between the cards and the distance between the lines filled by the sun's image.

D. Calculate the angular diameter of the sun.

Part II

A. Plot a graph of the sun's angular diameter versus time from the data table below.

OBSERVATIONS OF SOLAR DIAMETER
(Adapted from 1967 Amer. Ephemeris & Nautical Almanac)

Date	Angular Diameter	Date	Angular Diameter
Jan 1	32' 35.0"	July 10	31' 30.9"
Jan 10	32' 34.8"	July 20	31' 31.8"
Jan 20	32' 33.5"	July 30	31' 33.6"
Jan 30	32' 31.4"	Aug 10	31' 36.4"
Feb 10	32' 28.1"	Aug 20	31' 39.8"
Feb 20	32' 24.1"	Aug 30	31' 44.0"
Mar 1	32' 20.1"	Sept 10	31' 49.0"
Mar 10	32' 15.7"	Sept 20	31' 54.1"
Mar 20	32' 10.3"	Sept 30	31' 59.5"
Mar 30	32' 04.9"	Oct 10	32' 05.0"
Apr 10	31' 58.8"	Oct 20	32' 10.5"
Apr 20	31' 53.4"	Oct 30	32' 15.9"
Apr 30	31' 48.4"	Nov 10	32' 21.1"
May 10	31' 43.8"	Nov 20	32' 25.5"
May 20	31' 39.7"	Nov 30	32' 29.2"
May 30	31' 36.4"	Dec 10	32' 32.0"
June 10	31' 33.5"	Dec 20	32' 34.0"
June 20	31' 31.7"	Dec 30	32' 35.0"
June 30	31' 31.0"		

B. Analyze the graph and describe some possible explanations for its pattern.

QUESTIONS:

Part I

1. When the card with the image is moved away from the pinhole card, what happens to the size of the image? Why?

2. How can this size be expressed in terms of an angular measurement?

3. How could we calculate the sun's actual size by the method used in this investigation? What other information would be needed?

4. How would you measure the angular diameter of the moon?

5. What is the maximum difference in solar diameter on your graph? What is the percentage change?
Use the formula: percentage change = $\frac{\text{difference}}{\text{average}}$

(A-1.46) 6. What is the pattern of the changes in diameter of the sun?

(D-1.11) (D-1.21) 7. What are some possible models of earth-sun motions which could support your interpretation of the data?

(D-2.11) 8. What shape of orbit for the earth or sun would best satisfy the data in this investigation?

Easy (1)

IV-D-2a: ORBITS

QUESTION:

What models explain the observations of celestial and terrestrial motions?

MATERIALS:

Two thumbtacks, about 25 cm. of carpet thread, notebook size piece of corrugated cardboard, copy of an ellipse (see supplementary sheet).

SUGGESTED APPROACH:

1. Ask students to make a sketch of what they think the earth's orbit looks like. Ask them to describe the shape of the orbit, then introduce the investigation as a study of orbits and of the elliptical orbit of the earth.

2. Have students follow the steps under Method on the student version.

3. Lead the students in a discussion in which you compare the shape of the students' drawings with the shape of the earth's orbit. Ask them what observations could be made from earth that might suggest the shape of the earth's orbit.

MODIFICATIONS:

Make a scale model of the earth's orbit. How big does the model have to be before it begins to look elliptical?

REFERENCES:

Our Planet in Space, pp. 89-91.
Investigating the Earth, pp. 499-501.

IV-D-2a: ORBITS

QUESTION:

What models explain the observations of celestial and terrestrial motions?

INTRODUCTION:

Make a sketch of what you think the earth's orbit looks like. Save your sketch until the end of this investigation, then look at it again. In this investigation, you will make a study of orbital paths, in particular, the orbital path of the earth around the sun.

OBJECTIVES:

When you have finished this investigation you should be able to:

1. choose from among several given models the one that best represents the true shape of the earth's orbit.

METHOD:

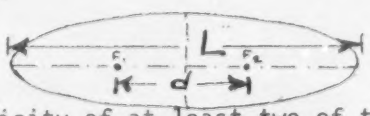
1. Put the blank paper on top of the cardboard and stick in two thumbtacks near the center of the paper. They should be about 3 centimeters apart. Tie a circle of string, with a circumference of about 20 cm., and loop it around the thumbtacks. With someone holding the tacks so that they don't pull out, place your pencil inside the loop, pull it taut, and move it around the tacks until you have completed a smooth closed curve.

2. Repeat step one several more times, varying first the distance between the tacks and then the length of the string.

3. On the predrawn orbit, compare the area inside the triangle drawn from focus A to the left-hand portion of the curve with the area of the triangle drawn from focus A to the right-hand portion of the curve. You can do it easily by counting squares. Measure and record the length of the arcs cutoff by the legs of each triangle.

4. Orbits are usually described in terms of their eccentricity (e) which is defined as the distance between the foci (d) divided by the length of the major axis (l):

$$e = \frac{d}{L}$$



Calculate and record the eccentricity of at least two of the orbits you constructed and of the predrawn orbit.

QUESTIONS:

1. What effect does changing the length of the string have on the shape of the orbit?

2. What effect does changing the distance between the foci (thumbtacks) have on the shape of the orbit?

(D-2.11) 3. What is the shape of the earth's orbit around the sun? Where is the sun located within the orbit?

(D-2.12) 4. What are the shapes of the orbits of the other planets? Where is the sun located within each of these orbits?

5. From the table below, which planets have the most eccentric orbits? Which have the most nearly circular orbits?

Name	Distance from Sun	Eccentricity of Orbit
Mercury	36 million miles	0.206
Venus	67	0.007
Earth	93	0.017
Mars	142	0.093
Jupiter	483	0.048
Saturn	886	0.056
Uranus	1780	0.047
Neptune	2790	0.008
Pluto	3670	0.247

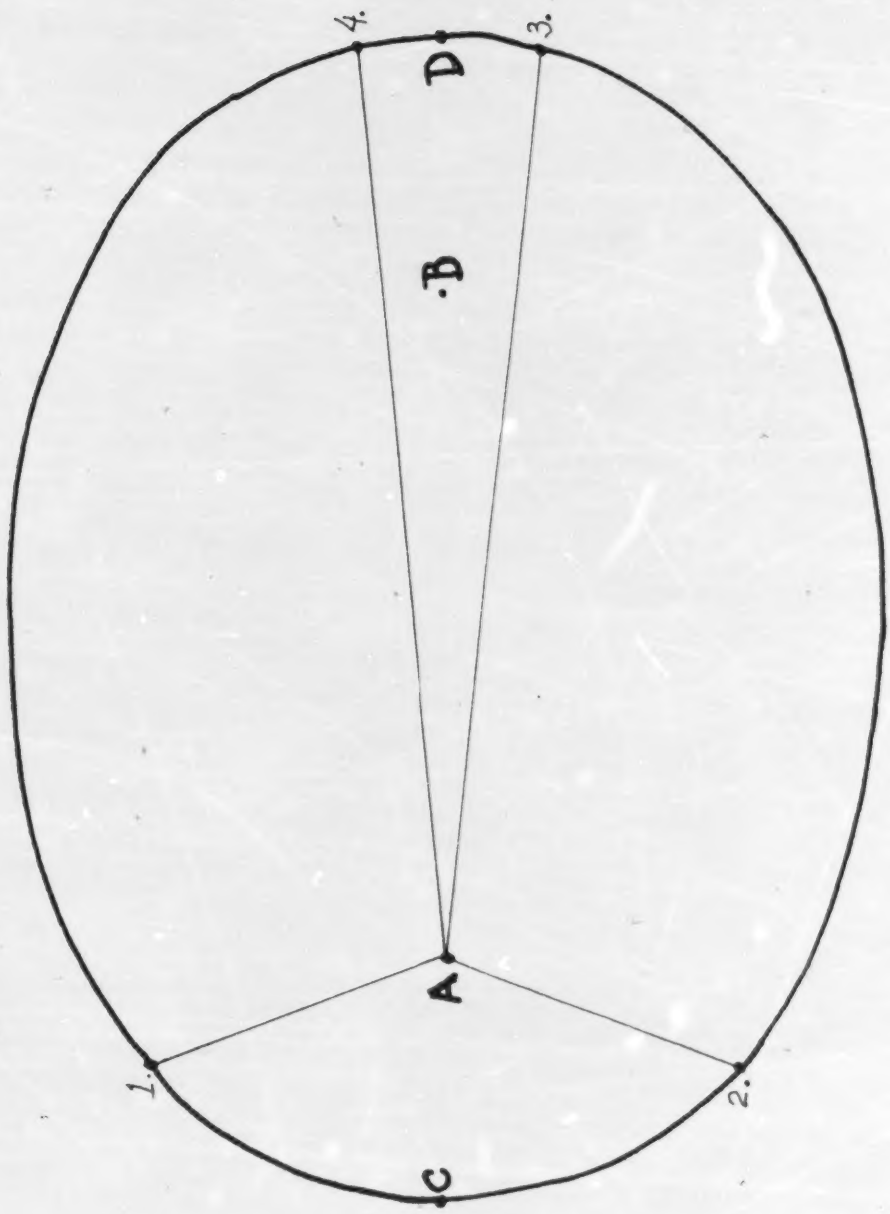
6. How does the eccentricity of the predrawn orbit compare with the eccentricity of the earth's orbit? With your first sketch of the earth's orbit?

(D-2.13) 7. A planet traveling along the predrawn orbit reached position 1 on December 14, 2 on December 29, 3 on June 14, and 4 on June 29. How many days does it take to travel from 1 to 2? From 3 to 4? What is the relationship between areas swept out by an imaginary line connecting the sun and a planet and the time necessary to accomplish this?

8. What effect could these changes in earth motion have on the length of day on the earth?

SUPPLEMENTARY SHEET

Predrawn Orbit

A and B are foci

C - D is the major axis